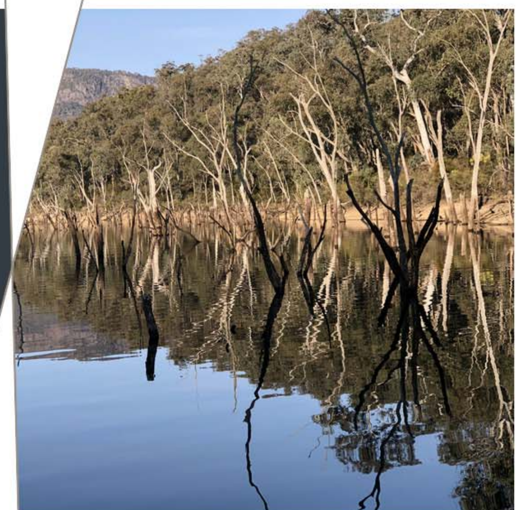
APPENDIX M.2

AQUATIC ECOLOGY IMPACT ASSESSMENT

Aquatic Ecology Assessment

Snowy 2.0 Main Works

59918111



Prepared for
EMM Consulting Pty Ltd

13 September 2019

Contact Information

Cardno (NSW/ACT) Pty Ltd

ABN 95 001 145 035

Level 9 - The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia

www.cardno.com
Phone +61 2 9496 7700
Fax +61 2 9439 5170

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Author(s):

Dan Pygas – Principal Aquatic Ecologist
Dr Brendan Alderson – Senior Aquatic Ecologist
Kate Reeds – Principal Aquatic Ecologist
Dr Craig Blount – Regional Senior Principal

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Approved By:

Dr Marcus Lincoln Smith
Senior Principal – Applied Ecology

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Executive Summary

Introduction

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) of on demand generating capacity, and providing approximately 350,000 megawatt hours (MWh) of storage available to the National Electricity Market (NEM) at any one time. Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground.

Snowy 2.0 has been declared to be State significant infrastructure (SSI) and critical State significant infrastructure (CSSI) by the former NSW Minister for Planning under Part 5 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act) and is defined as CSSI in clause 9 of Schedule 5 of the State Environmental Planning Policy (State and Regional Development) 2011 (SRD SEPP). CSSI is infrastructure that is deemed by the NSW Minister to be essential for the State for economic, environmental or social reasons. An application for CSSI must be accompanied by an environmental impact statement (EIS). Separate applications are being submitted by Snowy Hydro for different stages of Snowy 2.0 under Part 5, Division 5.2 of the EP&A Act. This includes the preceding first stage of Snowy 2.0, Exploratory Works for Snowy 2.0 (the Exploratory Works) and the stage subject of this current application, Snowy 2.0 Main Works (the Main Works).

This Aquatic Ecology Assessment (AEA) has been prepared to accompany an application and supporting Environmental Impact Statement (EIS) for the Snowy 2.0 Main Works. As the title suggests, this stage of the project covers the major construction elements of Snowy 2.0, including permanent infrastructure (such as the underground power station, power waterways, access tunnels, chambers and shafts), temporary construction infrastructure (such as construction adits, construction compounds and accommodation), management and storage of excavated rock material and establishing supporting infrastructure (such as road upgrades and extensions, water and sewage treatment infrastructure, and the provision of power for construction). Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

Existing environment

Key aquatic habitats and biota relevant to the project were determined through a comprehensive literature review, consultations with fisheries scientists, including the NSW Department of Primary Industries (NSW DPI) - Fisheries, database searches and a detailed program of field investigations.

The Snowy Hydro Scheme is situated within a large geographical region comprising lakes and watercourses interconnected by natural and artificial water bodies, largely located within Kosciuszko National Park (KNP). Key aquatic locations within the project area include Talbingo and Tantangara reservoirs and the Yarrangobilly, Eucumbene and Murrumbidgee rivers and some of their tributaries. Snowy 2.0 would establish a new two-way connection between Talbingo Reservoir and Tantangara Reservoir, enabling water from Talbingo Reservoir to enter the Murrumbidgee River, Snowy River, and Murray River catchments (**Figures ES1** and **Figure ES2**).

Talbingo Reservoir currently captures water released from Tumut 2 (T2) power station and creates a head storage for the operation of the Tumut 3 (T3) power station. It also receives water from natural catchment inflows, including from the Tumut and Yarrangobilly Rivers. It has a gross storage volume of 920 GL of water and its maximum depth is approximately 140 m below the dam crest.

Tantangara Reservoir occurs at a higher elevation than Talbingo Reservoir. It lies within a flat, alpine plateau and impounds the headwaters of the Murrumbidgee River for diversion through the Murrumbidgee-Eucumbene Tunnel to Lake Eucumbene for storage. Some water is also discharged into the Murrumbidgee River, primarily for environmental purposes. Water from the Goodradigbee River, a downstream tributary of the Murrumbidgee River, is also diverted to the reservoir via the Goodradigbee River Aqueduct, which is a one-way connection. Tantangara Reservoir receives water from natural catchment inflows mainly from the upper Murrumbidgee River, Nungar Creek and Mosquito Creek. The reservoir is smaller and shallower than Talbingo Reservoir with a gross capacity of 254 GL and a maximum depth of 33.3 m below FSL.

Surface and bottom waters of Talbingo Reservoir are generally a few degrees Celsius warmer than Tantangara Reservoir. Apart from during winter, Talbingo Reservoir has a thermocline at approximately 10 m depth. The thermocline in Tantangara Reservoir occurs in late Spring to Summer and exists between 5 and 10 m below the surface. In both reservoirs, water clarity generally restricts the photic zone to within a few metres of the surface.

Talbingo and Tantangara reservoirs and many of the streams within the project area are designated as key fish habitat (KFH) by NSW DPI (Fisheries). Aquatic habitats common to both reservoirs include 'unvegetated soft sediment', 'rocky rubble' and 'open water'. Additionally, Talbingo Reservoir contains 'aquatic plants' ('macrophytes') and 'submerged timber' (remaining from before the reservoir was filled with water). Tantangara Reservoir contains 'drowned grass tussocks and shrubs', 'rock boulders and emergent bedrock'. Primary productivity occurs in the shallower parts of the reservoirs, with macrophytes occurring in the littoral areas (more so in Talbingo Reservoir) and phytoplankton in the shallow open water. Zooplankton also occurs in open water. Benthic invertebrate communities inhabiting soft sediments occur in both reservoirs. Fish are prevalent in shallow littoral areas but may also occur in open water. In Talbingo Reservoir, these primarily include introduced fishes (including recreationally important salmonids and pest species) but also includes some native fishes (including a stocked population of the threatened trout cod, *Maccullochella macquariensis*). Salmonid populations and trout cod in Talbingo Reservoir are maintained by stocking from local trout hatcheries. There is less diversity of fish in Tantangara Reservoir and no threatened species. Recreationally important salmonids, including brown and rainbow trout (*Salmo trutta* and *Oncorhynchus mykiss*) occur in Tantangara Reservoir, but no other introduced fish species have been detected there. Freshwater crayfish occur in both reservoirs, including the threatened Murray crayfish (*Euastacus armatus*) in Talbingo Reservoir and Reik's crayfish (*E. reiki*) in Tantangara Reservoir as well as yabbies (*Cherax destructor*) in both reservoirs. The trout in Tantangara Reservoir are self-replenishing, i.e. populations are not stocked but are maintained by trout spawned in the reservoir's inflowing streams. The presence of Murray crayfish in Talbingo Reservoir means that this reservoir is classified as type 1 (highly sensitive) KFH, whilst Tantangara Reservoir is classified as type 2 (moderately sensitive).

Surrounding watercourses and reservoirs are currently connected to Talbingo or Tantangara reservoirs either by natural or man-made connections (i.e. a transfer tunnel). These reservoirs and their associated watercourses vary in the type and condition of aquatic habitat and biota. Watercourses upstream of each reservoir are generally in better condition than those downstream, because they are largely un-regulated and flow mostly through undisturbed native vegetation. Downstream of these reservoirs, much of the catchments surrounding many watercourses, pondages or other reservoirs are in farmland, with less native vegetation.

Murray crayfish occur in all proximal catchments upstream and downstream of Talbingo Reservoir, including the Yarrangobilly River. The critically endangered stocky galaxias (*Galaxias tantangara*) occurs upstream of the project area in the headwaters of Tantangara Creek, a tributary of the Murrumbidgee River upstream of Tantangara Reservoir. The aquatic ecological community of the Snowy River catchment in NSW has been listed as an endangered ecological community (EEC) under the *NSW Fisheries Management Act 1994*. Areas of the Snowy River EEC within the project area include upstream sections of the Eucumbene River Catchment above Lake Eucumbene. Salmonids occur in all catchments and most also include other types of non-native species. No other listed species or EECs are known to occur within the project area. A number of threatened species were identified to occur or potentially occur within the broader study area which also includes catchments downstream or in hydrologically connected locations. Based on the NSW Aquatic Pest and Disease Distribution map, *Lernaea* spp. (anchor worms) are suspected/anecdotally considered present and Epizootic Haematopoietic Necrosis Virus (EHNV), an iridovirus, is known to occur within the broader Murrumbidgee River catchment but has not been detected in either Talbingo or Tantangara reservoir or upstream catchments.

Assessment of impacts

The potential for direct and indirect impacts of the project on aquatic ecology within the project study area was assessed by determining the tolerances of habitats and biota to impacts from construction and operational stages of the Main Works. A risk assessment assisted with this process that considered the 'likelihood' of a potential impact pathway occurring and its 'consequences' were it to occur. Risk levels were identified as low, moderate, high or extreme and considered the effectiveness of project safeguards and mitigation measures at reducing risk. In addition to assisting with the assessment of impact, risk levels guide the level of management and / or mitigation, offsetting, monitoring or further research needed for the project.

Construction Phase

Aspects of Snowy 2.0 construction with potential to impact aquatic ecology include:

> Construction of intakes within Talbingo and Tantangara reservoirs including dredging and blasting works in each reservoir;

> Edge push placement of excavated rock and dredge material in Talbingo Reservoir;

> Dry placement of excavated rock above minimum operating level (MOL) in Tantangara Reservoir, designed to minimise impacts to aquatic ecology;

> Construction of a barge ramp at Tantangara Reservoir;

> Surface infrastructure and utilities, including waterway crossings and fish barriers;

> Tunnel dewatering into Talbingo and Tantangara reservoirs; and

> Tunnel excavation and groundwater drawdown.

Construction activities would occur in Talbingo and Tantangara reservoirs, in some of the catchments upstream of the reservoirs (including stream crossings) and within the catchment of Lake Eucumbene. While most of the construction activities occurring in the upstream catchments would be confined to the construction phase, some loss of habitat will be permanent. For example, there would be some permanent changes to aquatic habitat within the footprints of the intakes and a loss of some littoral habitats within the excavated material placement locations. For all activities, losses of aquatic habitat within construction footprints in the reservoirs or other catchments are very small in area relative to the large amount of similar habitat elsewhere in the reservoirs or the catchments. Other direct and indirect aspects of construction in catchments including construction areas, road crossings, the laying of communications cables and groundwater drawdown could affect isolated areas of the Snowy River EEC in the Eucumbene River Catchment and Type 1 KFH in a small part of the catchment of the Upper Murrumbidgee River. Fish barriers proposed as part of the project to limit the potential spread of pest fish would lead to a loss of a small amount of habitat within Tantangara Reservoir and Tantangara Creek.

The placement of excavated rock within Ravine Bay in Talbingo Reservoir, is predicted to change water quality, with consequential potential effects on aquatic ecology. A small proportion of the excavated material will be fines, which are predicted to remain suspended within the water column for significant periods of time before settling. A silt curtain will be deployed to contain material in suspension within the disturbance area, however, it is predicted that some will migrate beyond the curtain and settle outside the emplacement area. This could lead to a temporary decrease in photic depth and reduced primary productivity at least during the period of construction and possibly cause changes in the distribution of macrophytes (primarily exotic species) within the reservoir. Increased sedimentation could smother benthic invertebrates. Potential contamination from excavated rock is not expected since most of the rock would come from underground areas associated with the tunnels and underground power station, although some excavated rock would be 'potentially acid-forming' (PAF). Excavated rock would be stockpiled and screened for PAF before being allocated for reuse or placement in the reservoir.

Measures to manage the potential impacts to aquatic ecology, including the re-location of Murray crayfish out of the disturbance areas within Talbingo Reservoir, will be contained within the Dredging and Excavated Material Management Plan and the Aquatic Habitat Management Plan. The residual risk to aquatic ecology has been assessed as moderate.

Operational Phase

Aspects of Snowy 2.0 operational activities with potential to affect aquatic ecology include:

> Transfer of water between Talbingo Reservoir and Tantangara Reservoir potentially leading to;

  - Changes to physical and chemical characteristics of water within each reservoir;
  - Entrainment of biological material;
  - Transfer of fish between reservoirs;
  - Transfer of phytoplankton between reservoirs; and
  - Transfer of fish diseases between reservoirs.

> Maintenance or decommissioning of infrastructure and utilities;

> Ongoing groundwater drawdown; and

> Dewatering of the headrace and tailrace tunnel and station drainage.

The primary impact on physical and chemical characteristics of water from the Main Works would be changes in the reservoirs associated with the two-way water transfer. These changes would result in a new dynamic equilibrium being established in both reservoirs, with effects in Tantangara Reservoir expected to be greater than for Talbingo Reservoir given the different storage volumes and water depths. Only broad conclusions can be drawn about changes to water quality given the transfer regime will vary depending on Snowy Hydro operational decisions. Notwithstanding this, mixing of the reservoir waters during operation is unlikely to significantly affect pH, electrical conductivity, turbidity, dissolved oxygen concentration (except as a result of temperature changes); nutrients and metals (except for aluminium and copper) in either reservoir. The greatest potential change during operation would be in water temperature, particularly in Tantangara Reservoir. The risk of negative impacts to aquatic ecology from changes to water quality or temperature in the reservoirs is considered to be low.

Permanent infrastructure within catchments such as upgraded road crossings, permanent surface infrastructure or the intake structures in Talbingo or Tantangara reservoirs poses a low risk to aquatic ecology in any catchment given it would not directly affect fish passage or degrade waterways. Impaired water quality has the potential to occur in a limited number of watercourses above the tunnel associated with reduced flow from drawdown of surface water. Water quality in disconnected pool habitat could be reduced due to potential for elevated temperatures and reduced concentrations of dissolved oxygen particularly during summer. Given affected areas would be relatively small within the context of each catchment, the risk to aquatic ecology is considered low.

The transfer of water from Talbingo Reservoir to Tantangara Reservoir could potentially move pest species of fish (redfin perch, eastern gambusia, goldfish and climbing galaxias), phytoplankton or disease outside of their current range. In order for this to occur, fish must first occur in the area in front of the intake, be entrained into the intake during operation and then survive passage through the power station and 27 kms of tunnel. The results of experiments commissioned as part of investigations for this project has indicated that redfin perch and eastern gambusia could survive conditions designed to replicate aspects of transfer including shear stress, pressure and blade strike. Based on the available literature, the depth of the intake will often be outside the typical depth preferences of these species, although the possibility of them occurring there cannot be ruled out. Whether redfin perch and eastern gambusia will be entrained into the intake and survive transfer through the completed development in sufficient numbers to establish a population in Tantangara Reservoir, cannot be known with certainty until Snowy 2.0 becomes operational.

Notwithstanding this, introduction of redfin perch into Tantangara Reservoir could occur at some stage during the life of the project. Transfer of other fish species into Tantangara Reservoir is considered to be less likely. Risks associated with transfer of redfin perch include competition with and potential predation on fauna within Tantangara Reservoir. Similar but less likely risks occur for eastern gambusia, wild goldfish and climbing galaxias. Climbing galaxias, although native are considered translocated to the Murrumbidgee Catchment. They are capable of negotiating barriers and can compete with native species. If transferred to Tantangara Reservoir, there is a small risk of them interacting with the stocky galaxias, in the upper reach of Tantangara Creek. Whilst the likelihood of interaction is small, the consequence of such an interaction if it occurred would be great, due to the limited distribution of stocky galaxias.

Based on a review of available technologies, no reasonable and feasible measures have been identified that could guarantee the prevention of potential fish transfer from Talbingo to Tantangara reservoirs through Snowy 2.0. It was, however, identified that the potential impacts of fish transfer could be mitigated via the installation of fish barriers that would limit the potential range expansion of fish from Tantangara Reservoir into other catchments. The design of Snowy 2.0 includes a screening system capable of preventing fish transfer through the Murrumbidgee-Eucumbene tunnel to Lake Eucumbene and the Murrumbidgee river below Tantangara dam wall. A specially designed fish barrier is also proposed in Tantangara Creek just upstream of the waterfall upstream of Alpine Creek Trail. This barrier is designed to prevent movement of climbing galaxias into the upstream 4 km of Tantangara Creek above the waterfall where it may impact stocky galaxias. In conjunction with the increased ability to manage inflows and prevent spill from Tantangara Reservoir following the construction of Snowy 2.0, these barriers will largely prevent the potential for pest fish to enter the habitat of any known threatened species as a result of Snowy 2.0. Although there is some potential for impacts to occur within Tantangara Reservoir and some sections of the Upper Murrumbidgee catchment (rated as moderate to high risk), the likelihood of transfer and consequent impacts to other fish or any threatened species is rare.

The transfer of phytoplankton between reservoirs will most likely lead to populations becoming more similar within both reservoirs. Changes in the phytoplankton assemblage may affect other aquatic biota that consume or are otherwise associated with phytoplankton, although this is unlikely. There is also a low risk that there would be a transfer of species of phytoplankton capable of forming harmful algal blooms.

There is potential that water transfer could increase the range of the fish disease EHNV, which has not been identified in either Tantangara or Talbingo reservoirs. Redfin perch (and, to a lesser extent are rainbow trout) are known hosts for this disease. Several native species, including Macquarie perch, are susceptible to EHNV under laboratory conditions, although natural disease events caused by EHNV have never been detected in species other than redfin perch and rainbow trout. The fish barriers described above would be expected to reduce, but not eliminate, the risk of EHNV being transferred to the Murrumbidgee River downstream of Tantangara Reservoir in the event of an EHNV outbreak. The residual risk of this occurring was assessed as moderate. A monitoring program for EHNV is proposed as part of the project.

Although the potential effects of the various project hazards have been considered separately, there are likely to be interactions among impacts that could reduce or magnify the intensity of a response or raise or lower the threshold of response. Interactive effects of multiple impacts are poorly understood but given most of the impacts affect similar parts of the project area and a worst case scenario has been assumed for each impact (i.e. mortality to biota), then cumulative impacts would not change conclusions. Cumulative impacts may lengthen the recovery time in some areas for some habitats but not to the extent that it would change conclusions.

Conclusion

The Snowy Scheme is situated within a large geographical region comprising lakes and watercourses interconnected by natural and artificial water bodies. Many of the waterbodies in the project study contain important aquatic habitat and are of significant conservation value.

Construction and operational activities associated with Snowy 2.0 Main Works have potential to impact on aquatic ecology in some waterbodies in the project area, in particular the existing Talbingo and Tantangara reservoirs. The main potential for impact would be from construction activities within the reservoir and from the proposed connection between Talbingo Reservoir and Tantangara Reservoir, which would establish a new two way hydrologic pathway between these reservoirs.

The management of risks to aquatic ecology will occur via the mitigation measures and through the development of a range of management plans. These will contain measures to construct the proposed development in a way that seeks to minimise negative impacts on the aquatic environment and enable appropriate responses to impacts that are identified. Identified moderate residual risks include potential impacts to biota due to elevated suspended fine material associated with placement of excavated rock within Talbingo Reservoir during construction and potential impacts associated with the transfer of invasive species (fish and/or fish disease) between Talbingo and Tantangara reservoirs and into associated catchments during operation in the unlikely event of failure of all controls.

Mitigation of elevated TSS within Talbingo Reservoir would be primarily managed by deploying a silt curtain to minimise the spread of turbid water/suspended solids beyond the excavated material footprint and with strict adherence to the Dredging and Excavated Materials Management Plan and the Aquatic Habitat Management Plan.

In response to the risks of fish and/or fish disease transfer, Snowy Hydro has incorporated additional secondary controls at outflows of Tantangara Reservoir and above the waterfall on Tantangara Creek. These measures will limit the potential range expansion of any fish that may be transferred to Tantangara Reservoir as a result of the project and will prevent these fish from entering the known habitats of any threatened species, including the Murrumbidgee River below Tantangara Reservoir and Lake Eucumbene. These controls are a result of considerable volumes of research and design development initiated by Snowy Hydro aimed at reducing the potential risk to fish populations and other components of aquatic ecology at risk from fish transfer.

Given these findings, consideration of the proposed safeguards and the potential option for offsets in the event inadvertent damage to aquatic habitats or populations of biota occur, the project has acceptable outcomes to aquatic ecology values in the project study area.

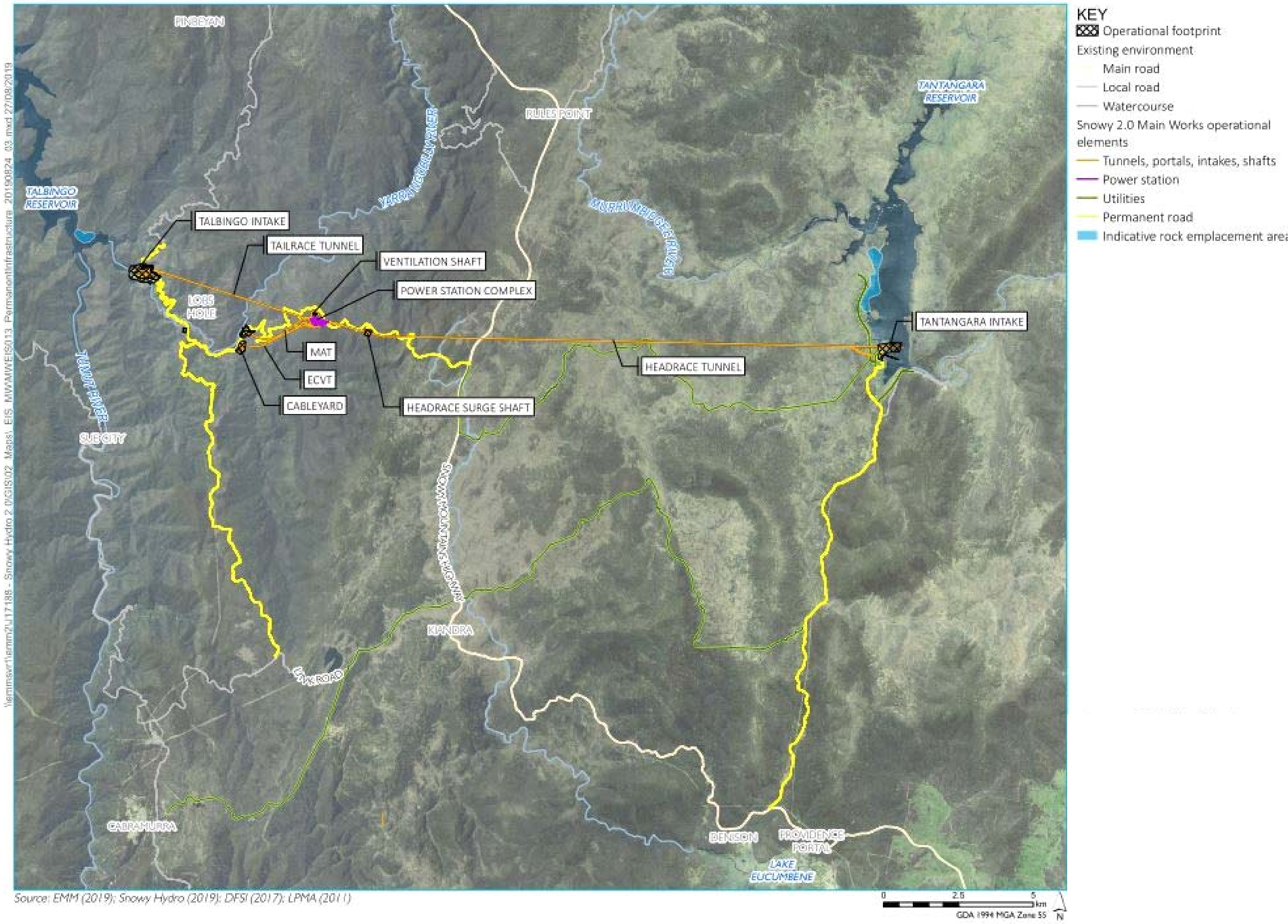

Figure ES1 Snowy 2.0 project overview

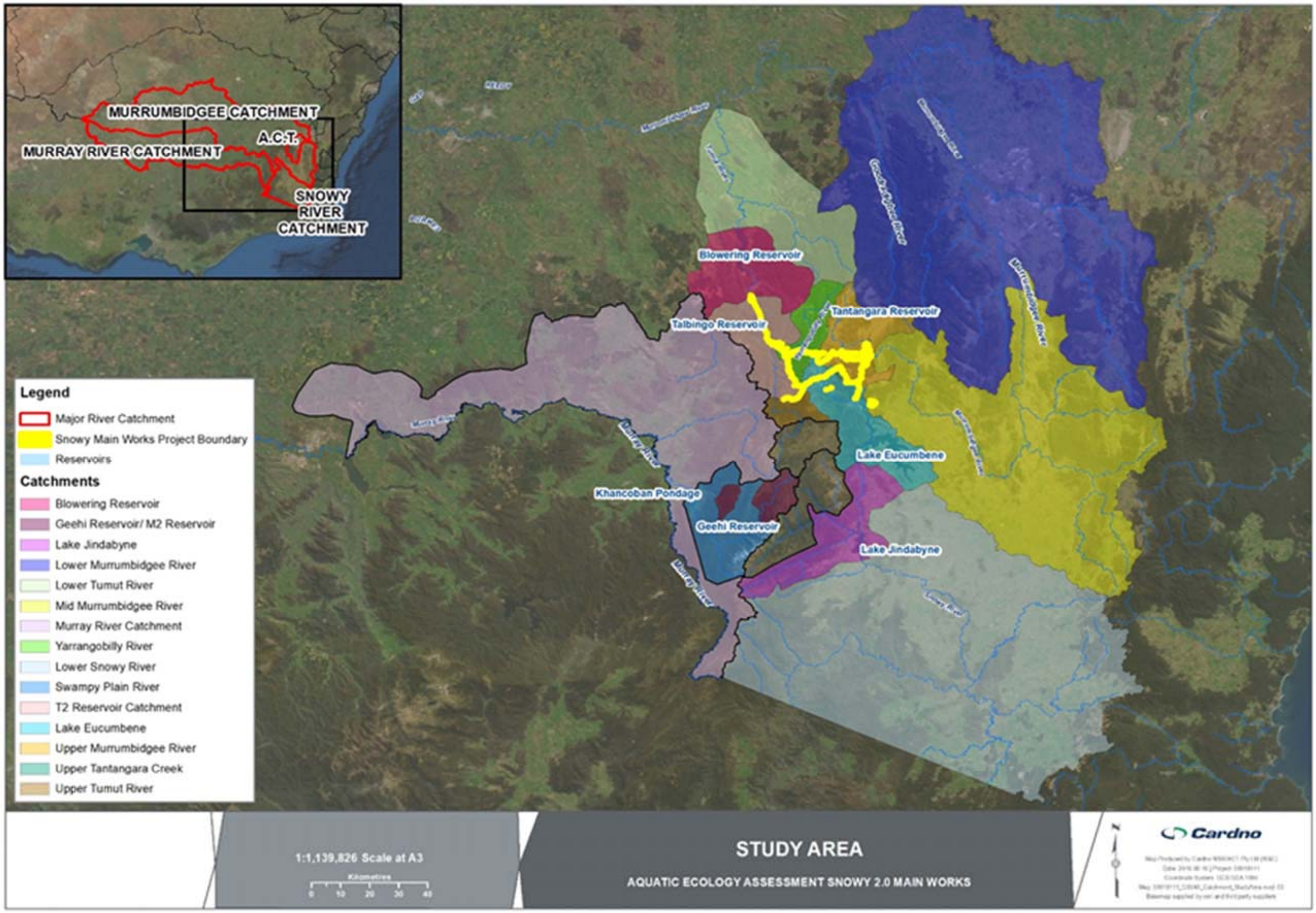

Figure ES2 Project study area, overlaid with the boundaries of the catchments

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Glossary and Abbreviations

Active storage	Storage between Full Supply Level (FSL) and Minimum Operating Level (MOL)
AEA	Aquatic Ecology Assessment
Adits	Adits are required to provide access during construction and for maintenance purposes. Construction adits are generally considered to be temporary tunnels.
AHD	Australian Height Datum, m (~ standard height measurement for Australian construction)
AqHMP	Aquatic Habitat Management Plan
BC Act	*Biodiversity Conservation Act 2016*
BMP	Biodiversity Management Plan
Cardno	Cardno NSW/ACT Pty Ltd
CSSI	Critical State Significant Infrastructure
DEMMP	Dredging and Excavated Materials Management Plan
DoE	Department of Environment
DoEE	Australian Department of Environment and Energy
DPIE	NSW Department of Planning, Industry and Environment
DPI	NSW Department of Primary Industries
ECVT	Emergency Egress, Cable and Ventilation Tunnel
EIS	Environmental Impact Statement
EHNV	Epizootic Haematopoietic Necrosis Virus
EMM	EMM Consulting
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
EPI	Environmental Planning Instrument
ESCP	Erosion and Sediment Control Plan
FM Act	*NSW Fisheries Management Act 1994*
FSL	Full Supply Level. (The normal maximum operating water level of a water storage when not affected by floods. This water level corresponds to 100% capacity).
HAB	Harmful algal bloom
Inactive storage	Storage below Minimum Operating Level (MOL) which is unable to be used by Snowy Hydro operational assets.
KFH	Key Fish Habitat
KNP	Kosciuszko National Park
KTP	Key Threatening Process
LGA	Local Government Area
MAT	Main Access Tunnel
MNES	Matters of National Environmental Significance as listed under the EPBC Act
MOL	Minimum Operating Level (The lowest level to which a reservoir can be drawn down under normal operating conditions and is the lower limit of active storage).
NEM	National Electricity Market
NPWS	National Parks and Wildlife Service

PFMP	Pest Fish Monitoring Plan
PMST	DoEE's Protected Matters Search Tool
Project area	The Project area is the broader region within which Snowy 2.0 will be built and operated, and the extent within which direct impacts from the Project are anticipated.
SEARs	Secretary's Environmental Assessment Requirements
Snowy Hydro	Snowy Hydro Limited
Snowy scheme	Snowy Mountains Hydro-Electric Scheme
SRD SEPP	*State Environmental Planning Policy (State and Regional Development) 2011*
SSI	State Significant Infrastructure
Study area	Study area for the Aquatic Ecology Assessment
TBM	Tunnel Boring Machine
WMP	Water Management Plan

1 Introduction

1.1 The Project

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground.

Snowy 2.0 has been declared to be State significant infrastructure (SSI) and critical State significant infrastructure (CSSI) by the former NSW Minister for Planning under Part 5 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined as CSSI in clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). CSSI is infrastructure that is deemed by the NSW Minister to be essential for the State for economic, environmental or social reasons. An application for CSSI must be accompanied by an environmental impact statement (EIS).

Separate applications are being submitted by Snowy Hydro for different stages of Snowy 2.0 under Part 5, Division 5.2 of the EP&A Act. This includes the preceding first stage of Snowy 2.0, Exploratory Works for Snowy 2.0 (the Exploratory Works) and the stage subject of this current application, Snowy 2.0 Main Works (the Main Works). In addition, an application under Part 5, Division 5.2 of the EP&A Act is also being submitted by Snowy Hydro for a segment factory that will make tunnel segments for both the Exploratory Works and Main Works stages of Snowy 2.0.

The first stage of Snowy 2.0, the Exploratory Works, includes an exploratory tunnel and portal and other exploratory and construction activities primarily in the Lobs Hole area of the Kosciuszko National Park (KNP). The Exploratory Works were approved by the former NSW Minister for Planning on 7 February 2019 as a separate project application to DPIE (SSI 9208).

This Aquatic Ecology Assessment (AEA) has been prepared to accompany an application and supporting EIS for the Snowy 2.0 Main Works. As the title suggests, this stage of the project covers the major construction elements of Snowy 2.0, including permanent infrastructure (such as the underground power station, power waterways, access tunnels, chambers and shafts), temporary construction infrastructure (such as construction adits, construction compounds and accommodation), management and storage of excavated rock material and establishing supporting infrastructure (such as road upgrades and extensions, water and sewage treatment infrastructure, and the provision of construction power). Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

Snowy 2.0 Main Works is shown in **Figure 1-1**. If approved, the Snowy 2.0 Main Works would commence before completion of Exploratory Works.

The Snowy 2.0 Main Works do not include the transmission works proposed by TransGrid (TransGrid 2018) that provide connection between the cableyard and the NEM. These transmission works will provide the ability for Snowy 2.0 (and other generators) to efficiently and reliably transmit additional renewable energy to major load centres during periods of peak demand, as well as enable a supply of renewable energy to pump water from Talbingo Reservoir to Tantangara Reservoir during periods of low demand. While the upgrade works to the wider transmission network and connection between the cableyard and the network form part of the CSSI declaration for Snowy 2.0 and Transmission Project, they do not form part of this application and will be subject to separate application and approval processes, managed by TransGrid. This project is known as the HumeLink and is part of AEMO's Integrated System Plan.

With respect to the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), on 30 October 2018 Snowy Hydro referred the Snowy 2.0 Main Works to the Commonwealth Department of the Environment and Energy (DoEE) and, on a precautionary basis, nominated that Snowy 2.0 Main Works has potential to have a significant impact on MNES and the environment generally.

On 5 December 2018, Snowy 2.0 Main Works were deemed a controlled action by the Assistant Secretary of the DoEE. It was also determined that potential impacts of the project will be assessed by accredited assessment under Part 5, Division 5.2 of the EP&A Act. This accredited process will enable the NSW

Department of Planning, Industry and Environment (DPIE) to manage the assessment of Snowy 2.0 Main Works, including the issuing of the assessment requirements for the EIS. Once the assessment has been completed, the Commonwealth Minister for the Environment will make a determination under the EPBC Act.

1.2 Project Location

Snowy 2.0 Main Works are within the Australian Alps, in southern NSW, about mid-way between Canberra and Albury. Snowy 2.0 Main Works is within both the Snowy Valleys and Snowy Monaro Regional local government areas (LGAs).

The nearest large towns to Snowy 2.0 Main Works are Cooma and Tumut. Cooma is located about 50 kilometres (km) south east of the project area (or 70 km by road from Providence Portal at the southern edge of the project area), and Tumut is located about 35 km north west of the project areas (or 45 km by road from Tumut 3 power station at the northern edge of the project area). Other townships near the project area include Talbingo, Cabramurra, Adaminaby and Tumbarumba. Talbingo and Cabramurra were built for the original Snowy Scheme workers and their families, while Adaminaby was relocated in 1957 to make way for the establishment of Lake Eucumbene.

The location of Snowy 2.0 Main Works with respect to the region is shown in **Figure 1-1**.

The pumped hydro-electric scheme elements of Snowy 2.0 Main Works are mostly underground between the southern ends of Talbingo and Tantangara reservoirs, a straight-line distance of 27 km. Surface works would also occur at locations on and between the two reservoirs. Key locations for surface works include:

> **Tantangara Reservoir** - at a full supply level (FSL) of about 1,229 metres (m) to Australian Height Datum (AHD), Tantangara Reservoir will be the upper reservoir for Snowy 2.0 and include the headrace tunnel and intake structure. The site will also be used for a temporary construction compound, accommodation camp and other temporary ancillary activities;

> **Marica** - this site will be used primarily for construction including construction of vertical shafts to the underground power station (ventilation shaft) and headrace tunnel (surge shaft), and a temporary accommodation camp;

> **Lobs Hole** - the site will be used primarily for construction but will also become the main entrance to the power station during operation. Lobs Hole will provide access to the Exploratory Works tunnel, which will be refitted to become the main access tunnel (MAT), as well as the location of the emergency egress, cable and ventilation tunnel (ECVT), portal, associated services and accommodation camp; and

> **Talbingo Reservoir** - at a FSL of about 546 m AHD, Talbingo Reservoir will be the lower reservoir for Snowy 2.0 and will include the tailrace tunnel and water intake structure. The site will also be used for temporary construction compounds and other temporary ancillary activities.

Works will also be required within the two reservoirs for the placement of excavated rock and surplus cut material. Supporting infrastructure will include establishing or upgrading access tracks and roads and electricity connections to construction sites.

Most of the proposed pumped hydro-electric and temporary construction elements and most of the supporting infrastructure for Snowy 2.0 Main Works are located within the boundaries of KNP, although the disturbance footprint for the project during construction is less than 0.25% of the total KNP area. Some of the supporting infrastructure and construction sites and activities (including sections of road upgrade, power and communications infrastructure) extends beyond the national park boundaries. These sections of infrastructure are primarily located to the east and south of Tantangara Reservoir. One temporary construction site is located beyond the national park along the Snowy Mountains Highway about 3 km east of Providence Portal (referred to as Rock Forest).

The project is described in more detail in **Section 2**.

1.2.1 Project Area

The project area for Snowy 2.0 Main Works has been identified and includes all the elements of the project, including all construction and operational elements. The project area is shown on **Figure 1-1**. Key features of the project area are:

> the water bodies of Tantangara and Talbingo reservoirs, covering areas of 19.4 square kilometres (km^2) and 21.2 km^2 respectively. The reservoirs provide the water to be utilised in Snowy 2.0;

> major watercourses including the Yarrangobilly, Eucumbene and Murrumbidgee rivers and some of their tributaries;
> KNP, within which the majority of the project area is located. Within the project area, KNP is characterised by two key zones: upper slopes and inverted treelines in the west of the project area (referred to as the 'ravine') and associated subalpine treeless flats and valleys in the east of the project area (referred to as the 'plateau'); and
> farm land southeast of KNP at Rock Forest.

The project area is interspersed with built infrastructure including recreational sites and facilities, main roads as well as unsealed access tracks, hiking trails, farm land, electricity infrastructure, and infrastructure associated with the Snowy Scheme.

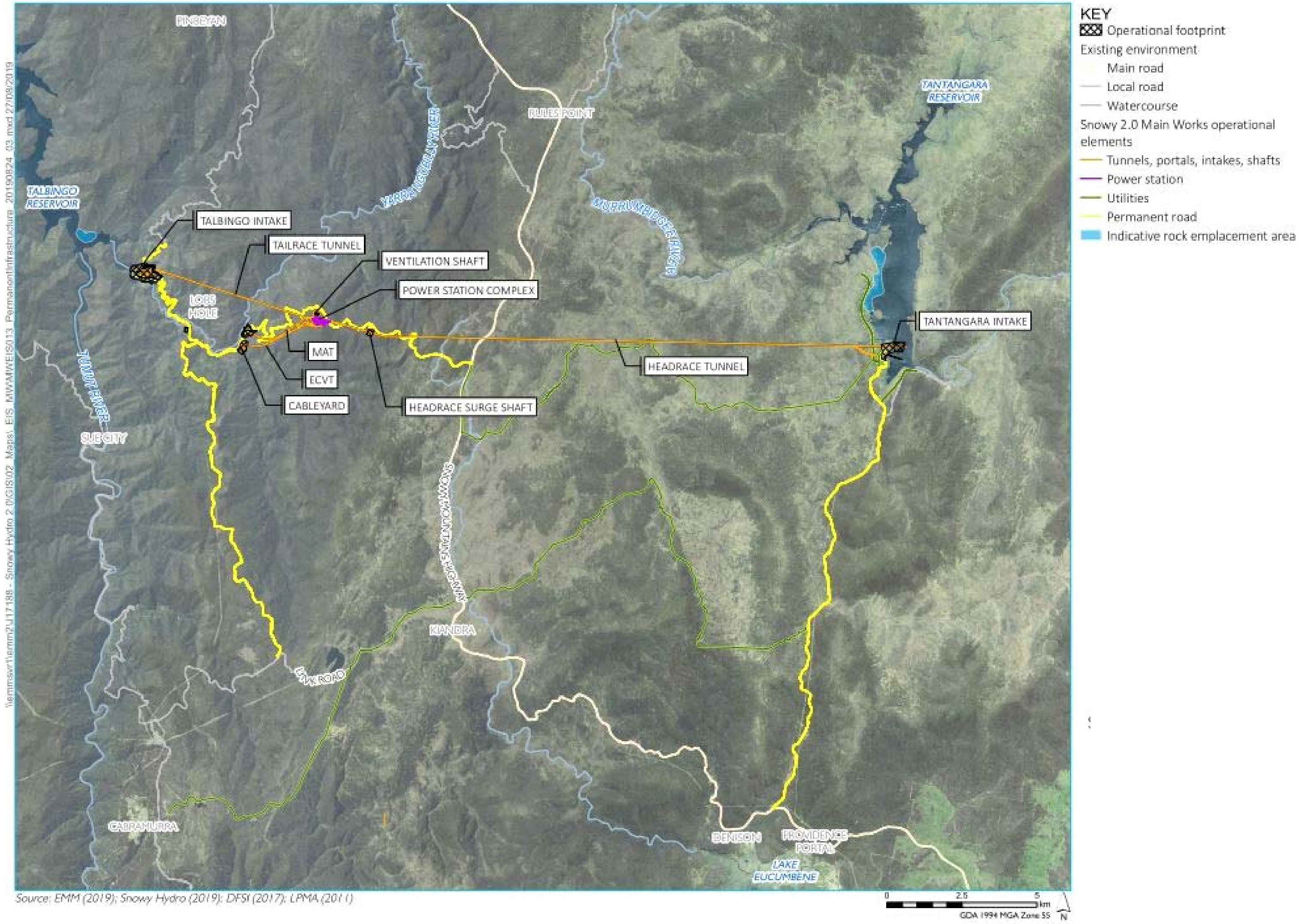

Figure 1-1 Snowy 2.0 project overview

1.2.2 Aquatic Ecology Study Area

The study area relevant to this AEA encompasses the reservoirs and catchments that have been considered in relation to potential impacts (both direct and indirect) from Snowy 2.0 Main Works and/or referenced within this report for comparative purposes. At a broad-scale, the study area includes the project area, Talbingo and Tantangara Reservoirs and the broader areas associated with the Tumut River, Murrumbidgee River, Snowy River and Upper Murray Catchments and sub-catchments (i.e. major tributaries). These divisions were based on ecological and physical criteria, primarily geographic context, hydrological connectivity (i.e. the presence of artificial and natural barriers to the movement of aquatic biota), aquatic habitat types (e.g. still versus flowing water) and the known distribution of key species. This helped conceptualise and discriminate the different ecological attributes that may or may not be affected by Snowy 2.0 and thereby facilitate the impact assessment. **Table 1-1** and **Figure 1-2** identify the components of the aquatic ecology study area and the primary waterbodies included in the assessment. The aquatic ecological investigations undertaken within each waterbody / catchment are also indicated.

Table 1-1 Description of the study area, including Talbingo Reservoir, Tantangara Reservoir and the associated catchments and sub-catchments.

Component of study area	Primary Waterbodies
Tumut River Catchment	
Talbingo Reservoir	Talbingo Reservoir up to full supply level (FSL)
Yarrangobilly River Catchment	Yarrangobilly River including Wallace's Creek, Lick Hole Creek, Sheep Station Creek, Cave Gully upstream of Talbingo Reservoir FSL.
Upper Tumut River Catchment	Tumut River below Tumut 2 Reservoir dam wall and all other tributaries flowing into Talbingo Reservoir upstream of FSL (except Yarrangobilly River Catchment, see above).
T2 Reservoir Catchment	Tumut River upstream of Tumut 2 Reservoir, including Tumut Pond Reservoir, Tumut River and tributaries upstream to Happy Jacks Pondage dam wall.
Blowering Reservoir Catchment	Blowering Reservoir catchment downstream of Talbingo Dam Wall, including Blowering Reservoir, Jounama Pondage, and associated tributaries.
Lower Tumut Catchment	Catchment of the Tumut River from Blowering Dam Wall to the confluence with the Murrumbidgee River
Tantangara River Catchment	
Tantangara Reservoir	Tantangara Reservoir up to FSL
Upper Murrumbidgee River Catchment	Tributaries of Tantangara Reservoir, including the upper Murrumbidgee River, Tantangara Creek up to Tantangara Creek Waterfall just upstream of Alpine Creek Trail, Nungar Creek, Gooandra Creek, Kelly's Plain Creek, Mufflers Creek, Mosquito Creek and Goodradigbee River above the diversion weir.
Upper Tantangara Creek	Tantangara Creek u/s of Tantangara Creek Waterfall (just upstream of Alpine Creek Trail crossing).
Mid Murrumbidgee River Catchment	Murrumbidgee River Catchment between Tantangara Dam and ACT/NSW Border), including Murrumbidgee River, Numeralla River and other tributaries.
Lower Murrumbidgee River Catchment	Murrumbidgee River Catchment from the ACT/NSW border downstream to Lake Burrinjuck. Includes the Goodradigbee River below the diversion weir with a confluence at Lake Burrinjuck.
Eucumbene and Snowy River catchments	
Lake Eucumbene Catchment	Eucumbene Reservoir up to FSL and its tributaries, including the upper Eucumbene River, Gang Gang Creek and Three Mile Creek.

Lake Jindabyne Catchment	Lake Jindabyne up to FSL and its tributaries, including Snowy River catchment upstream of Lake Jindabyne to Island Bend dam wall, Gungarlin River Catchment upstream to Burrungubugee and Gungarlin Weirs and Thredbo River.
Lower Snowy River Catchment	Snowy River and its tributaries downstream of Lake Jindabyne dam wall.
Murray River Catchment	
Murray River to Hume Reservoir Catchment	Murray River Catchment from its headwaters downstream to Hume Reservoir including the Swampy Plains River Catchment below Khancoban dam wall
Swampy Plain River Catchment	Swampy Plain River upstream of Khancoban dam wall, including Khancoban Reservoir and associated tributaries including Khancoban Back Creek to M2 Reservoir dam wall and Geehi River to Geehi Reservoir dam wall, .
Geehi River and Murray 2 (M2) Reservoir catchments	Geehi River Catchment from Geehi Dam upstream (including Geehi Reservoir) and Khancoban Back Creek catchment from M2 dam wall (including M2 Reservoir) upstream.

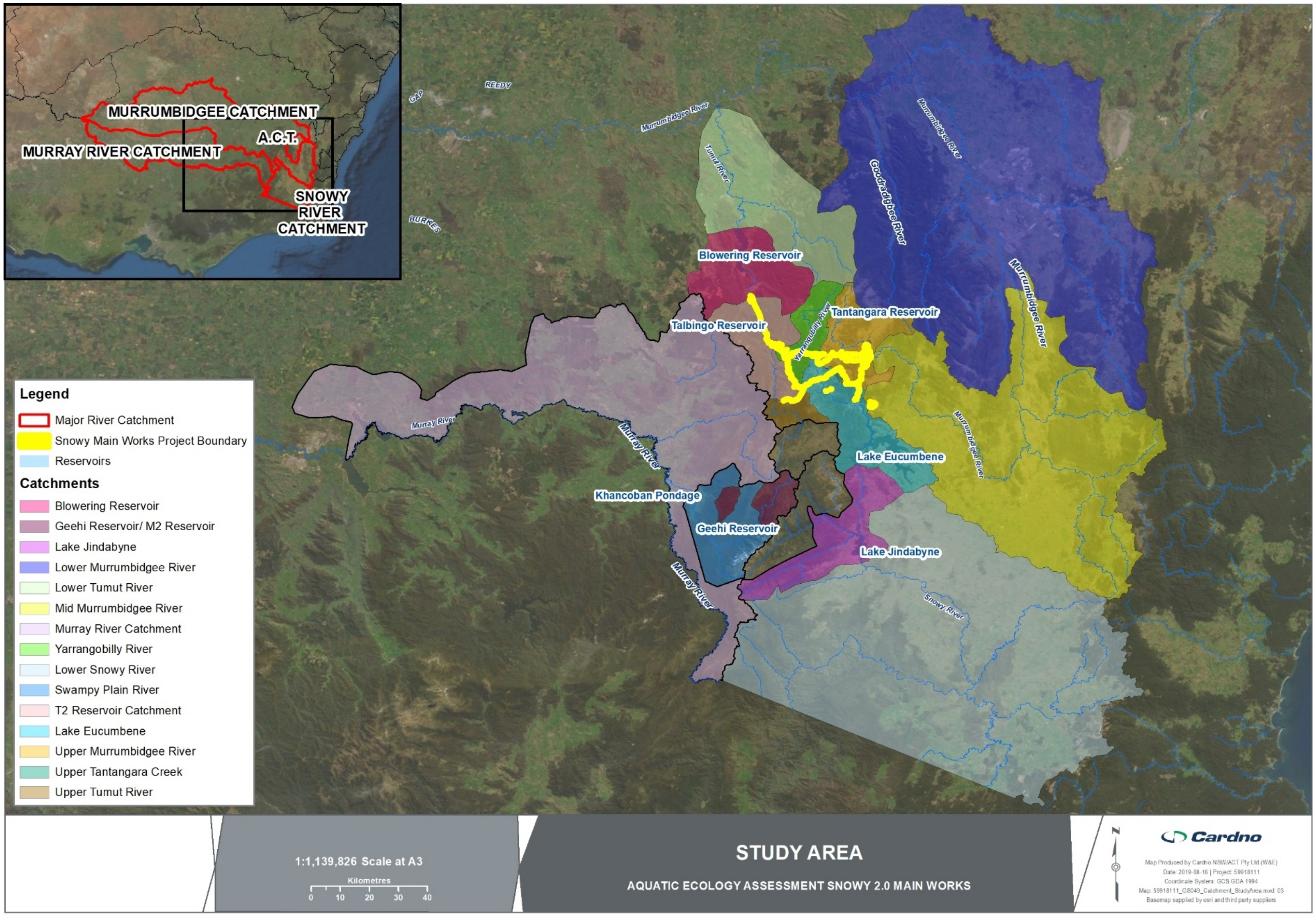

Figure 1-2 Study area, overlaid with the boundaries of the catchments with the study area, as described in Table 1-1

1.3 Proponent

Snowy Hydro is the proponent for the Snowy 2.0 Main Works. Snowy Hydro is an integrated energy business – generating energy, providing price risk management products for wholesale customers and delivering energy to homes and businesses. Snowy Hydro is the fourth largest energy retailer in the NEM and is Australia's leading provider of peak, renewable energy.

1.4 Purpose of this Report

This AEA supports the EIS for the Snowy 2.0 Main Works. It documents the aquatic ecology assessment methods and results, the initiatives built into the project design to avoid and minimise associated impacts to aquatic habitats and biota, and the mitigation and management measures, including offset requirements, proposed to address any unavoidable residual impacts (i.e. residual impacts are those potential impacts remaining after mitigative measures, if practicable, have been applied).

The specific objectives of this assessment are to:

> describe the existing biodiversity values and existing environment;

> identify and assess the potential presence of biodiversity values including threatened species and communities under relevant legislation including the NSW *Fisheries Management Act 1994* (FM Act), NSW *Biodiversity Conservation Act 2017* (BC Act) and EPBC Act;

> identify ecological constraints within and impacts arising from the Snowy 2.0 Main Works; and

> provide mitigation measures to reduce the impacts from the project on biodiversity wherever possible.

1.4.1 Assessment Guidelines and Requirements

This AEA has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for Snowy 2.0 Main Works, issued on 31 July 2019, the relevant government assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs must be addressed in the EIS. **Table 1-2** lists the SEARs matters relevant to this aquatic ecology assessment and where they are addressed in this report.

Table 1-2 Matters raised in the Snowy 2.0 Main Works SEARs relevant to aquatic ecology

Requirement	Section(s) Addressed
Relevant State and Commonwealth legislation, policies and guidelines	Section 3
Key features of the environment that could affect or be affected by the project	Section 5 Annexure A Annexure B
An assessment of the biodiversity impacts of the project on terrestrial, aquatic and groundwater-dependent ecosystems, including listed Commonwealth and State threatened species and communities and listed Commonwealth migratory species	Sections 6 and 7 Annexure C
A strategy to offset the residual impacts of the project on these ecosystems, focusing on enhancing the biodiversity values of the Kosciuszko National Park in the medium to long term	Section 9

To inform preparation of the SEARs, the DPIE invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPIE when preparing the SEARs.

1.5 Related Projects

There are three other projects related to Snowy 2.0 Main Works:

> Snowy 2.0 Exploratory Works (SSI-9208) – a Snowy Hydro project with Minister's approval;

> Snowy 2.0 Transmission Connect Project (SSI-9717) – a project proposed by TransGrid; and

> Snowy 2.0 Segment Factory (SSI-10034) – a project proposed by Snowy Hydro.

While these projects form part of the CSSI declaration for Snowy 2.0 and Transmission Project, they do not form part of Snowy Hydro's application for Snowy 2.0 Main Works. These related projects are subject to separate application and approval processes. Staged submission and separate approval is appropriate for a project of this magnitude, due to its complexity and funding and procurement processes. However, cumulative impacts have been considered in this report where relevant.

1.6 Other Relevant Reports

This AEA has been prepared with reference to other technical reports prepared as part of the Snowy 2.0 Main Works EIS. The reports referenced in this AEA include:

> Groundwater assessment (EMM 2019a) – Appendix J of the EIS;

> Surface water assessment (EMM 2019a) – Appendix J of the EIS;

> Biodiversity Development Assessment Report (EMM 2019a) – Appendix M.1 of the EIS;

> Water Assessment Report (EMM 2019a) – Appendix J of the EIS; and

> Snowy 2.0 Subaqueous Excavated Rock Placement, Model Development, Calibration and Scenario Model Investigations (RHDHV 2019).

2 Description of the Project

This chapter provides a summary of the Snowy 2.0 Main Works project. It outlines the functional infrastructure required to operate Snowy 2.0, as well as the key construction elements and activities required to build it. A more comprehensive detailed description of the project is provided in Chapter 2 (Project description) of the EIS, which has been relied upon for the basis of this technical assessment.

2.1 Overview of Snowy 2.0

Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground. An overview of Snowy 2.0 is shown on **Figure 1-1,** and the key project elements of Snowy 2.0 are summarised in **Table 2-1**.

Table 2-1 Overview of Snowy 2.0 Main Works

Project element	Summary of the project
Project area	The project area is the broader region within which Snowy 2.0 will be built and operated, and the extent within which direct impacts from Snowy 2.0 Main Works are anticipated.
Permanent infrastructure	Snowy 2.0 infrastructure to be built and operated for the life of the assets include the: • intake and gate structures and surface buildings at Tantangara and Talbingo reservoirs; • power waterway tunnels primarily comprising the headrace tunnel, headrace surge structure, inclined pressure tunnel, pressure pipelines, tailrace surge tank and tailrace tunnel; • underground power station complex comprising the machine hall, transformer hall, ventilation shaft and minor connecting tunnels; • access tunnels (and tunnel portals) to the underground power station comprising the main access tunnel (MAT) and emergency egress, communication, and ventilation tunnel (ECVT); • establishment of a portal building and helipad at the MAT portal; • communication, water and power supply including the continued use of the Lobs Hole substation; • cable yard adjacent to the ECVT portal to facilitate the connection of Snowy 2.0 to the NEM; • access roads and permanent bridge structures needed for the operation and maintenance of Snowy 2.0 infrastructure; and • fish control structures on Tantangara Creek and near Tantangara Reservoir wall.
Temporary infrastructure	Temporary infrastructure required during the construction phase of Snowy 2.0 Main Works are: • construction compounds, laydown, ancillary facilities and helipads; • accommodation camps for construction workforce; • construction portals and adits to facilitate tunnelling activities; • barge launch ramps; • water and wastewater management infrastructure (treatment plants and pipelines); • communication and power supply; and • temporary access roads.
Disturbance area	The disturbance area is the extent of construction works required to build Snowy 2.0. The maximum disturbance area is about 1,680 hectares (ha), less than 0.25% of the total area of KNP. Parts of the disturbance area will be rehabilitated and landformed and other parts will be retained permanently for operation (operational footprint).
Operational footprint	The operational footprint is the area required for permanent infrastructure to operate Snowy 2.0. The maximum operational footprint is about 99 ha. This is 0.01% of the total area of KNP.

Project element	Summary of the project
Tunnelling and excavation method	The primary tunnelling method for the power waterway is by tunnel boring machine (TBM), with portals and adits using drill and blast methods. Excavation for other underground caverns, chambers and shafts will be via combinations of drill and blast, blind sink, and/or raise bore techniques.
Excavated rock management	Excavated rock will be generated as a result of tunnelling activities and earthworks. The material produced through these activities will be stockpiled and either reused by the contractor (or NPWS), placed permanently within Tantangara or Talbingo reservoirs, used in final land forming and rehabilitation of construction pads in Lobs Hole, or transported offsite.
Construction water and wastewater management	Water supply for construction will be from the two existing reservoirs (Talbingo and Tantangara) and reticulated via buried pipelines (along access roads). Raw water will be treated as necessary wherever potable water is required (eg at accommodation camps). Water to be discharged (comprising process water, wastewater and stormwater) will be treated before discharge to the two existing reservoirs (Talbingo and Tantangara) as follows: • treated process water will be reused onsite where possible to reduce the amount of discharge to reservoirs, however excess treated water will be discharged to the reservoirs; • collected sewage will be treated at sewage treatment plants to meet the specified discharge limits before discharge and/or disposal; and • stormwater will be captured and reused as much as possible.
Rehabilitation	Rehabilitation of areas disturbed during construction including reshaping to natural appearing landforms or returning to pre-disturbance condition, as agreed with NPWS and determined by the rehabilitation strategy. This includes construction areas at Lobs Hole which comprise surplus cut materials that are required for the construction. Areas to be used by Snowy Hydro in the long-term may be re-shaped and rehabilitated to maintain access and operational capabilities (eg intakes and portal entrances).
Construction workforce	The construction workforce for the project is expected to peak at around 2,000 personnel.
Operational life	The operational life of the project is estimated to be 100 years.
Operational workforce	The operational workforce is expected to be 8-16 staff, with fluctuations of additional workforce required during major maintenance activities.
Hours of operation	Construction of Snowy 2.0 will be 24/7 and 365 days per year. Operation of Snowy 2.0 will be 24/7 and 365 days per year.
Capital investment value	Estimated to be $4.6 billion.

2.2 Construction of Snowy 2.0

A number of construction activities will be carried out concurrently, and across a number of different sites. Specific details on these activities as well as an indicative schedule of construction activities is provided in Chapter 2 (Project description) of the EIS. This section summarises the key construction elements of the project.

Table 2-2 provides an overview of the proposed construction elements, their purpose and location within the Project area.

Table 2-2 Snowy 2.0 proposed construction elements

Construction element	Purpose	Location
Construction sites	Due to the remoteness of Snowy 2.0, construction sites are generally needed to: • Provide ancillary facilities such as concrete batching plants, mixing plants and on-site manufacturing;	Each construction site needed for Snowy 2.0 is shown on **Figure 2.1** to **Figure 2.5**.

Construction element	Purpose	Location
	• Store machinery, equipment and materials to be used in construction; • Provide access to underground construction sites; and Provide onsite accommodation for the construction workforce.	
Substations and power connection	One substation is required to provide permanent power to Snowy 2.0, at Lobs Hole. This substation is proposed as part of a modification to the Exploratory Works with a capacity of 80 mega volt amp (MVA). It will continue to be used for Main Works, however requires the establishment of further power supply cables to provide power to the work sites and TBM at Tantangara, as well as Talbingo, in particular to power the TBMs via the MAT, ECVT, Talbingo and Tantangara portals.	The supporting high voltage cable route mostly follows access roads to each of the work sites, using a combination of aerial and buried arrangements.
Communications system	Communications infrastructure will connect infrastructure at Tantangara and Talbingo reservoirs to the existing communications system at the Tumut 3 power station (via the submarine communications cable in Talbingo Reservoir established during Exploratory Works) and to Snowy Hydro's existing communications infrastructure at Cabramurra.	The cable will be trenched and buried in conduits within access roads. Crossing of watercourses and other environmentally sensitive areas will be carried out in a manner that minimises environmental impacts where possible, such as bridging or underboring.
Water and waste water servicing	Drinking water will be provided via water treatment plants located at accommodation camps. Water for treatment will be sourced from the nearest reservoir. There are three main wastewater streams that require some form of treatment before discharging to the environment, including: • Tunnel seepage and construction wastewater (process water); • Domestic sewer (wastewater); and Construction site stormwater (stormwater).	Utility pipelines generally follow access roads. Water treatment plants (drinking water) will be needed for the accommodation camps and will be located in proximity. Waste water treatment plants will similarly be located near accommodation camps. Process water treatment plants will be at construction compounds and adits where needed to manage tunnel seepage and water during construction.
Temporary and permanent access roads	Access road works are required to: • provide for the transport of excavated material between the tunnel portals and the excavated rock emplacement areas; • accommodate the transport of oversized loads as required; and • facilitate the safe movement of plant, equipment, materials and construction workers into and out of construction sites. The access road upgrades and establishment requirements are shown on Figure 2.2 to Figure 2.7. These roads will be used throughout construction including use of deliveries to and from site and the external road network. Some additional temporary roads will also be required within the footprint to reach excavation fronts such as various elevations of the intakes excavation or higher benches along the permanent roads.	The access road upgrades and establishment requirements are shown across the project area. Main access and haulage to site will be via Snowy Mountains Highway, Link Road and Lobs Hole Ravine Road (for access to Lobs Hole), and via Snowy Mountains Highway and Tantangara Road (for access to Tantangara Reservoir) (see **Figure 1.1**).
Excavated rock management	Approximately 9 million m^3 (unbulked) of excavated material will be generated by construction and require management. The strategy for management of excavated rock will aim to maximise beneficial reuse of materials for construction activities. Beneficial re-use of excavated material may include use for road base, construction pad establishment, selected fill and	Placement areas are shown on **Figure 2.1** and **Figure 2.5**.

Construction element	Purpose	Location
	tunnel backfill and rock armour as part of site establishment for construction. Excess excavated material that cannot be re-used during construction will be disposed of within Talbingo and Tantangara reservoirs, used in permanent rehabilitation of construction pads to be left in situ in Lobs Hole, or transported for on-land disposal if required.	
Barge launch facilities	Barge launch facilities on Talbingo Reservoir will have already been established during Exploratory Works for the placement of the submarine communications cable, and will continued to be used for Main Works for construction works associated with the Talbingo intake structure. The Main Works will require the establishment of barge launch facilities on Tantangara Reservoir to enable these similar works (removal of the intake plug).	Barge launch sites are shown on **Figure 2.1** and **Figure 2.5**.
Construction workforce	The construction workforce will be accommodated entirely on site, typically with a FIFO/DIDO roster. Private vehicles will generally not be permitted and the workforce bused to and from site.	Access to site will be via Snowy Mountains Highway

The key areas of construction are shown on **Figure 2-1** to **Figure 2-7** and are described across the following locations:

> Talbingo Reservoir – Talbingo Reservoir provides the lower reservoir for the pumped hydro-electric project and will include the tailrace tunnel and water intake structure. The site will also be used for temporary construction compounds and other temporary ancillary activities;

> Lobs Hole – this site will be used primarily for construction (including construction of the MAT and ECVT portals and tunnels to the underground power station and the headrace tunnel (and headrace tunnel surge shaft), underground tailrace surge shaft and a temporary accommodation camp);

> Marica – the site will be used primarily for construction to excavate the ventilation shaft to the underground power station as well as for the excavation and construction of the headrace surge shaft;

> Plateau – the land area between Snowy Mountains Highway and Tantangara Reservoir is referred to as the Plateau. The Plateau will be used to access and construct a utility corridor and construct a fish weir on Tantangara Creek;

> Tantangara Reservoir – Tantangara Reservoir will be the upper reservoir for the pumped hydro project and include the headrace tunnel and intake structure. The site will also be used for a temporary construction compound, accommodation camp and other temporary ancillary activities; and

> Rock Forest – a site to be used temporarily for logistics and staging during construction. It is located beyond the KNP along the Snowy Mountains Highway about 3 km east of Providence Portal.

During the construction phase, all work sites will be restricted access and closed to the public. This includes existing road access to Lobs Hole via Lobs Hole Ravine Road. Restrictions to water-based access and activities will also be implemented for public safety and to allow safe construction of the intakes within the reservoirs. Access to Tantangara Reservoir via Tantangara Road will be strictly subject to compliance with the safety requirements established by the contractor.

A key construction element for the project is the excavation and tunnelling for underground infrastructure including the power station, power waterway (headrace and tailrace tunnels) and associated shafts (**Figure 2-1**). Further detail on construction methods provided at Appendix D of the EIS.

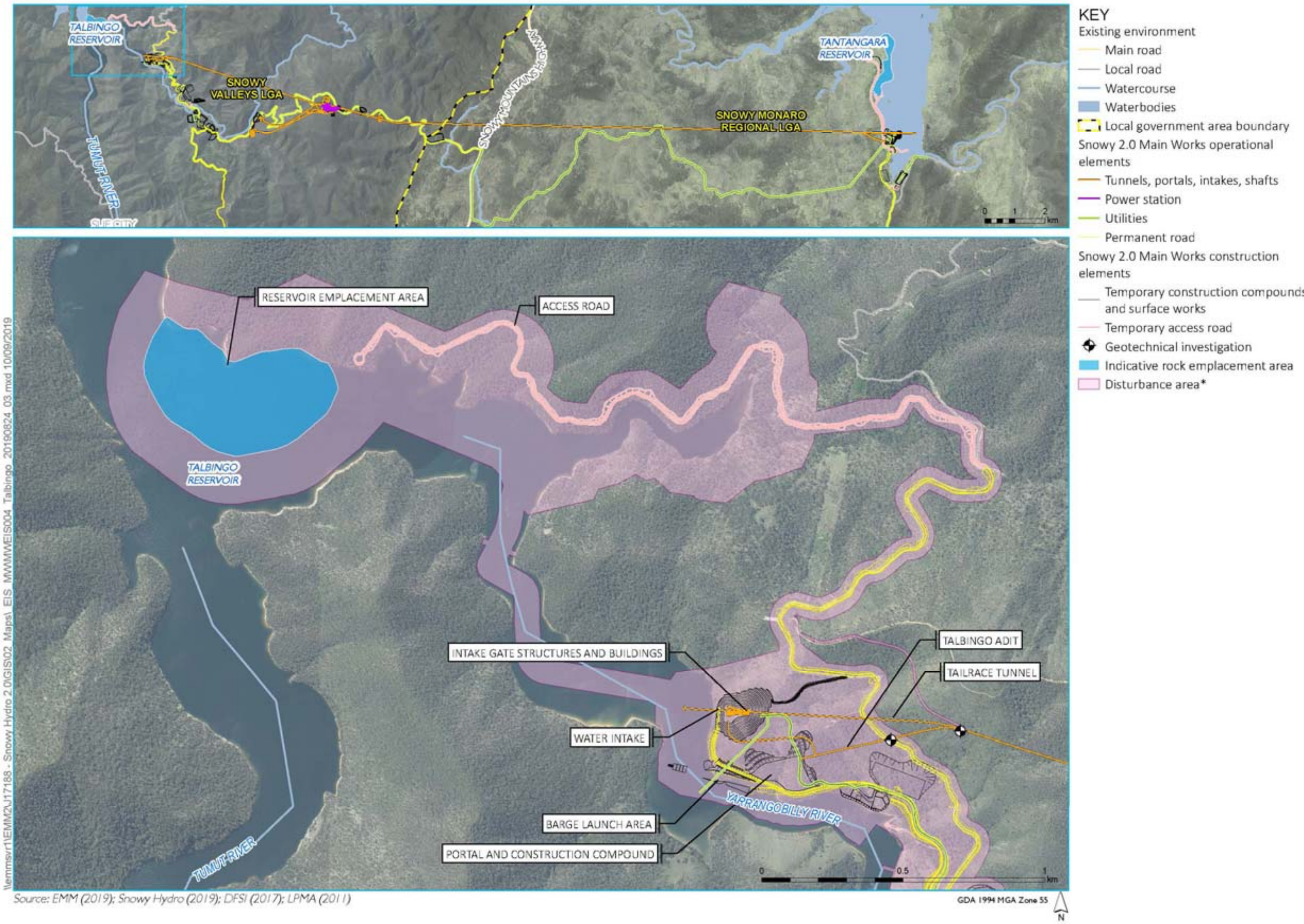

Figure 2-1 Snowy 2.0 locational areas – Talbingo Reservoir

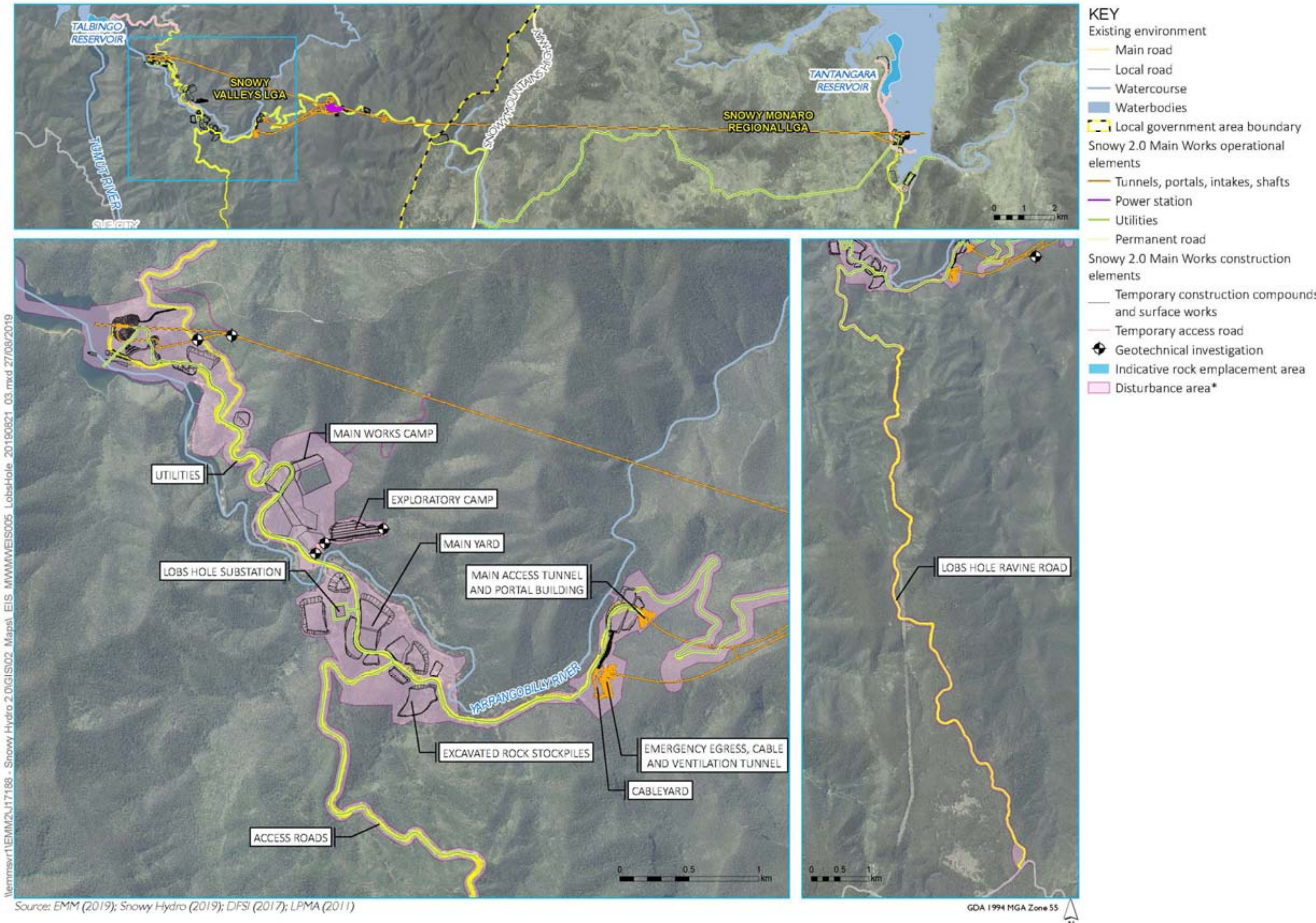

Figure 2-2 Snowy 2.0 locational areas – Lobs Hole

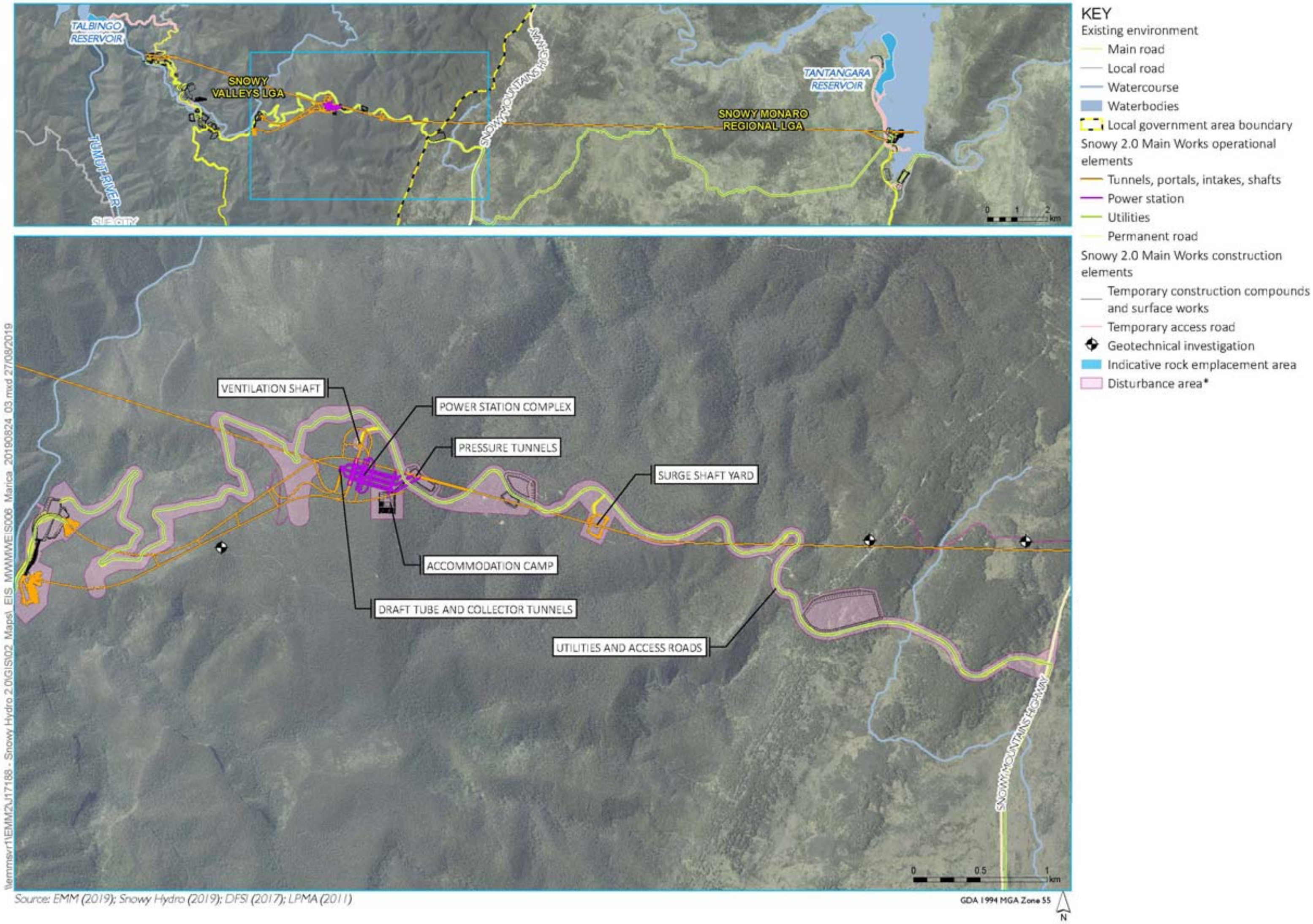

Figure 2-3 Snowy 2.0 locational areas – Marica

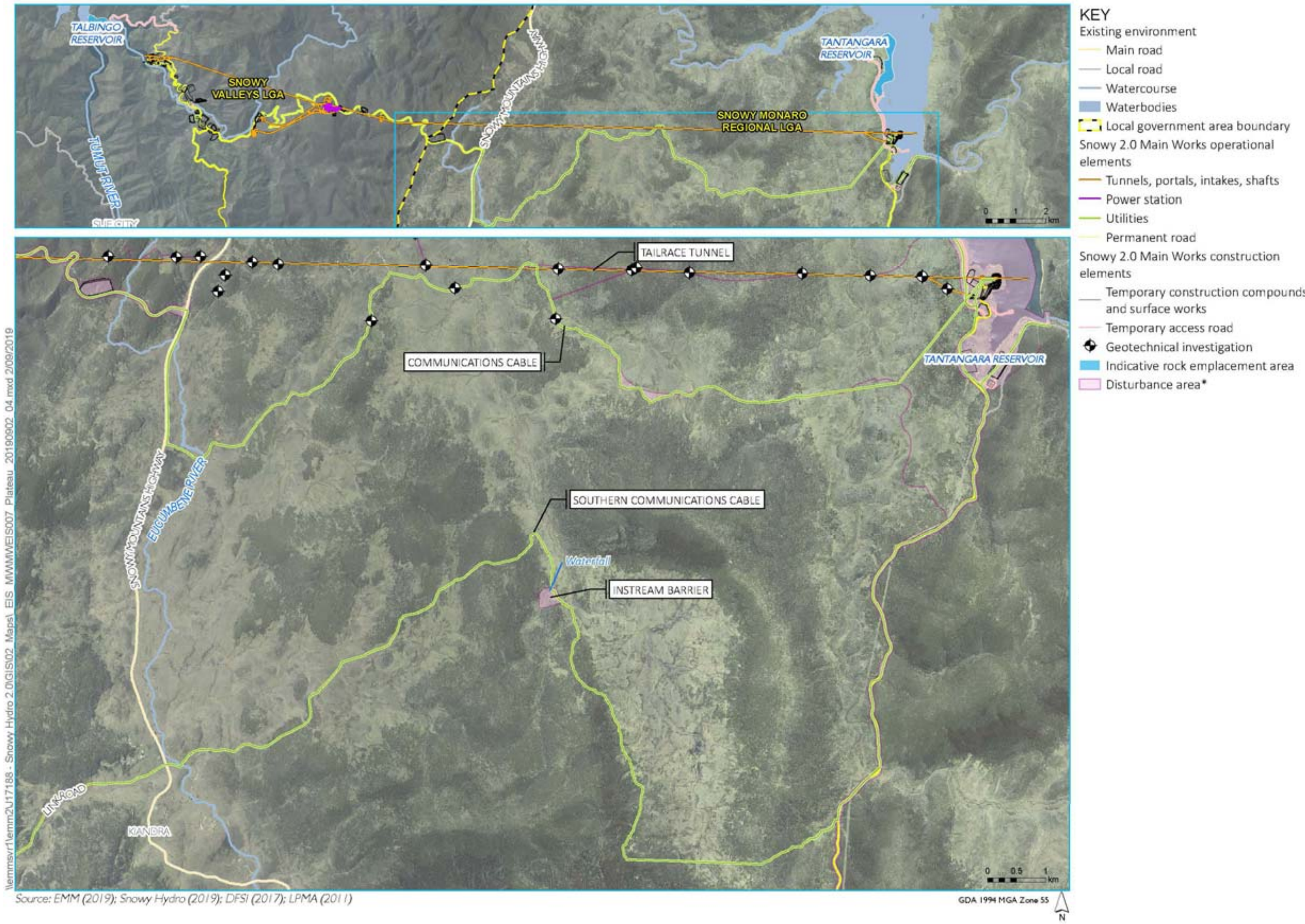

Figure 2-4 Snowy 2.0 locational areas – Plateau

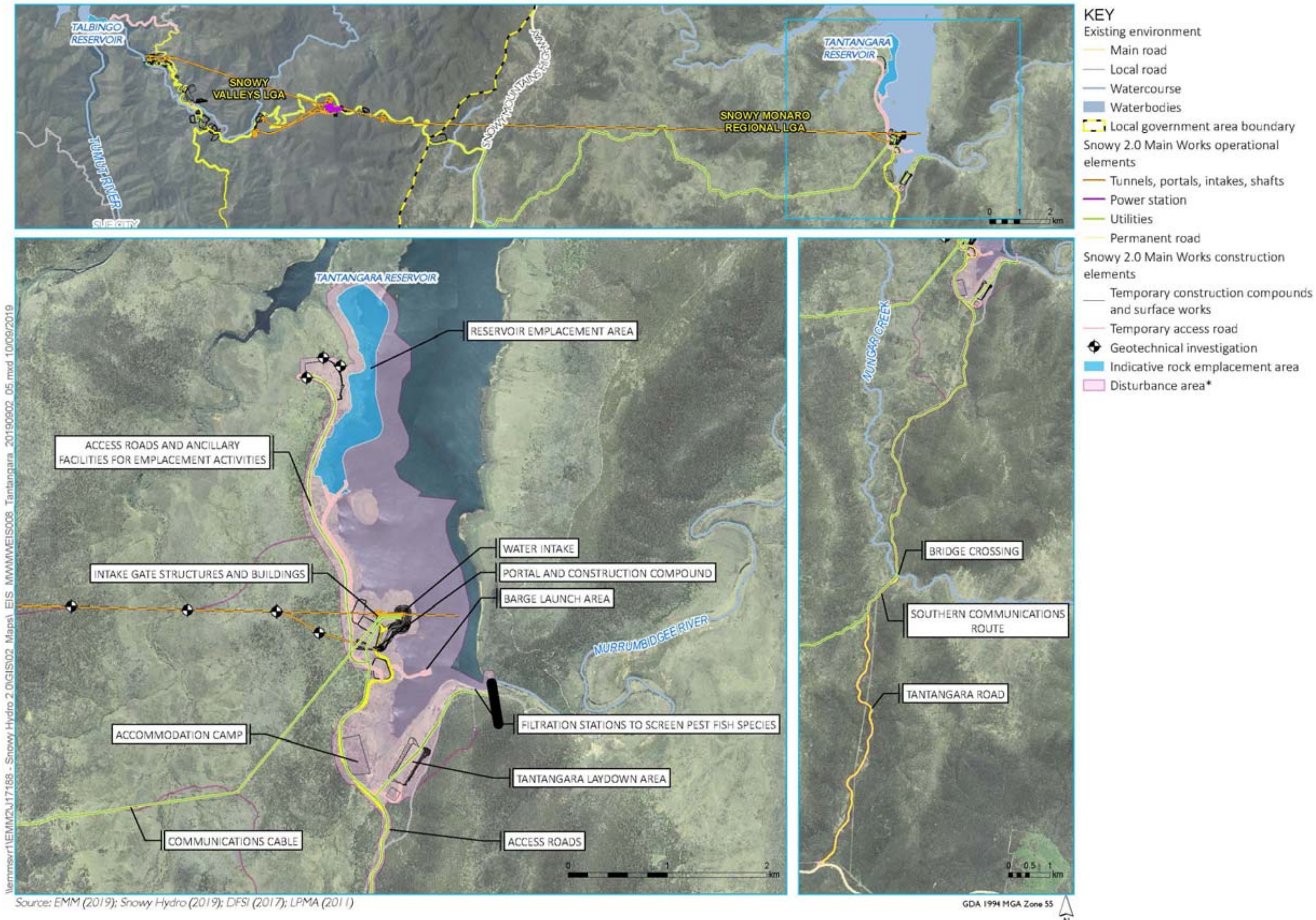

Figure 2-5 Snowy 2.0 locational areas – Tantangara

Figure 2-6 Snowy 2.0 locational areas – Rock Forest

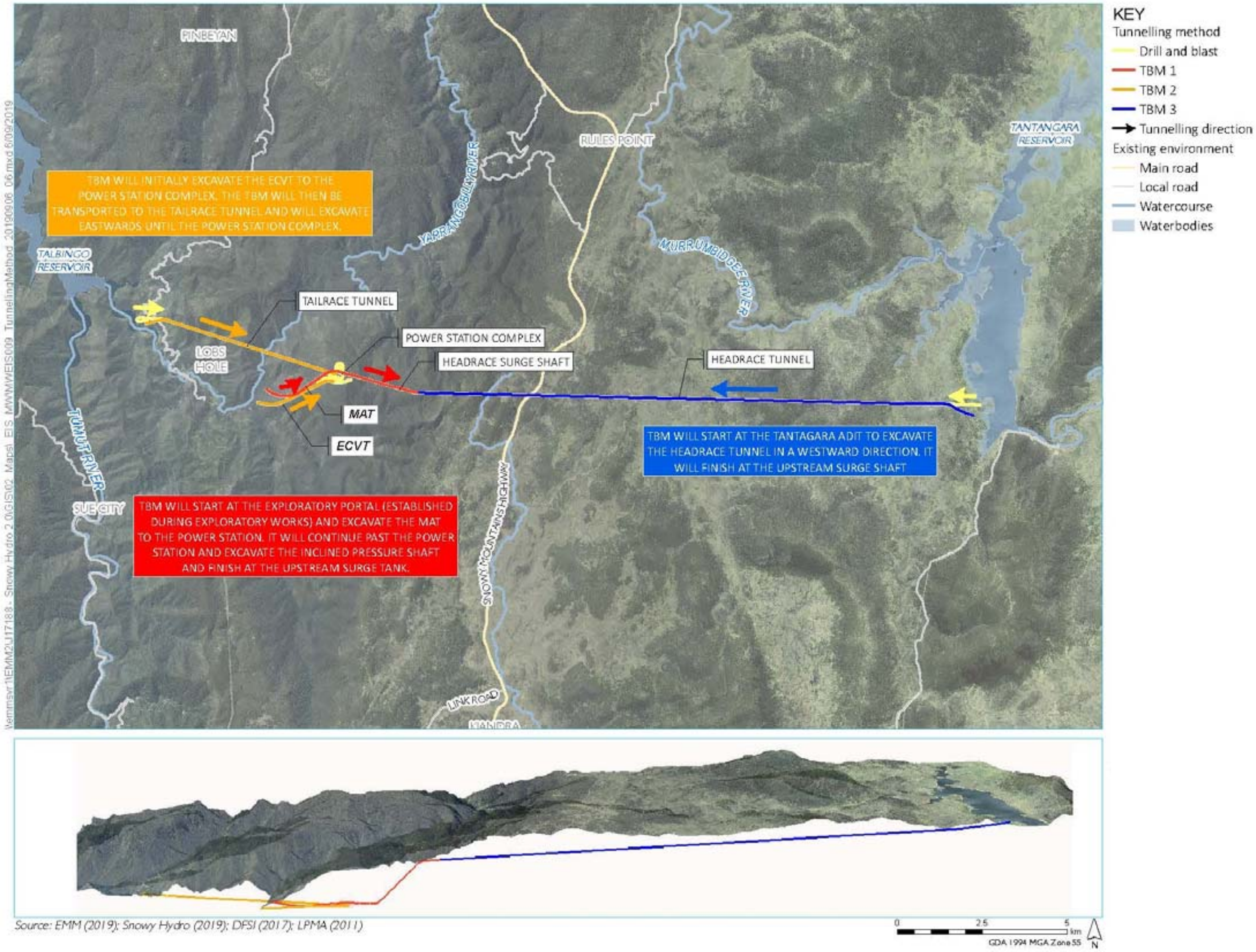

Figure 2-7 Snowy 2.0 locational areas – Excavation and tunnelling methods

2.3 Operation of Snowy 2.0

2.3.1 Scheme Operation and Reservoir Management

Snowy 2.0 would operate within the northern Snowy-Tumut Development, connecting the existing Tantangara and Talbingo reservoirs.

Tantangara Reservoir currently has the following operational functions within the Snowy Scheme:

> collects releases from the Murrumbidgee River and the Goodradigbee River Aqueduct,

> provides a means for storage and diversion of water to Lake Eucumbene via the Murrumbidgee-Eucumbene Tunnel, and

> provides environmental and riparian releases through the Tantangara Reservoir river outlet gates to the Murrumbidgee River.

Talbingo Reservoir currently has the following operational functions:

> collects releases from Tumut 2 power station,

> collects inflows from the Yarrangobilly and Tumut rivers,

> acts as head storage for water pumped up from Jounama Pondage by Tumut 3 power station, and

> acts as head storage for generation at Tumut 3 power station.

Due to its historical relationship to both the upstream Tumut 2 Power Station and downstream Tumut 3 Power Station, Talbingo Reservoir has more operational functions than Tantangara Reservoir in the current Snowy Scheme.

Following commencement of Snowy 2.0 operations, both Tantangara and Talbingo reservoirs will have increased operational functions. Tantangara Reservoir will act as a head storage for generation from the Snowy 2.0 power station and also acting as a storage for water pumped up from Talbingo Reservoir. Talbingo Reservoir will act as a tail storage from Snowy 2.0 generation and pumping.

As a result of Snowy 2.0 operations, the water level in Tantangara Reservoir will be more variable than historically; although operations will not affect release obligations under the Snowy Water Licence nor will it involve any change to the current Full Supply Levels (FSLs). No additional land will be affected by virtue of inundation of the reservoirs through Snowy 2.0 operations. Water storages will continue to be held wholly within the footprint of the existing FSLs.

2.3.2 Permanent Access

Permanent access to Snowy 2.0 infrastructure is required by Snowy Hydro. During operation, a number of service roads established during construction will be used to access surface infrastructure including the power station’s ventilation shaft, intake structures and gates, and the headrace tunnel surge shaft. Permanent access tunnels (the MAT and ECVT) will be used to access the power station.

2.3.3 Maintenance Requirements

Maintenance activities required for Snowy 2.0 will be integrated with maintenance activities for the existing Snowy Scheme. Required maintenance activities will include:

> maintenance of equipment and systems within the power station complex, intake structures, gates and control buildings;

> maintenance of access roads (vegetation clearing, pavement works, snow clearing);

> dewatering of the tailrace and headrace tunnel (estimated at once every 15 to 50 years, or as required); and

> maintenance of electricity infrastructure (cables, cable yard, cable tunnel).

2.4 Rehabilitation and Final Land Use

A Rehabilitation Strategy has been prepared for Snowy 2.0 Main Works and appended to the EIS

It is proposed that all areas not retained for permanent infrastructure will be revegetated and rehabilitated. At Lobs Hole, final landform design and planning has been undertaken to identify opportunities for the reuse of excavated material in rehabilitation to provide landforms which complement the surrounding topography in the KNP.

Given that most of Snowy 2.0 Main Works is within the boundaries of the KNP, Snowy Hydro will liaise closely with NPWS to determine the extent of decommissioning of temporary construction facilities and rehabilitation activities to be undertaken following construction of Snowy 2.0 Main Works.

3 Legislative Context

3.1 NSW *Environmental Planning and Assessment Act (1979)*

The *Environmental Planning and Assessment Act 1979* (EP&A Act) institutes a system of environmental planning and assessment in NSW and is administered by the NSW Department of Planning, Industry and Environment (DPIE). Part 5, Division 5.2 outlines the environmental assessment and approval requirements for state significant infrastructure (SSI). SSI can be declared to be critical (CSSI) if it is of a category that, in the opinion of the NSW Minister for Planning is essential for the State for economic, environmental or social reasons. The Snowy 2.0 Main Works has been declared CSSI.

Approval from the Minister for Planning is required for CSSI.

3.2 NSW *Fisheries Management Act (1994)*

The *Fisheries Management Act 1994* (FM Act) contains provisions for the conservation of fish stocks, key fish habitat (KFH), biodiversity, threatened species, populations and ecological communities. It regulates the conservation of fish, vegetation and some aquatic macroinvertebrates and the development and sharing of the fishery resources of NSW.

The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 lists key threatening processes (KTPs) for species, populations and ecological communities in NSW waters and declared critical habitats are listed in a register kept by the Minister of Primary Industries.

Impacts to these species, population, communities, processes and habitats due to the Snowy 2.0 Main Works need to be considered and assessed as part of the impact assessment. The assessment guidelines made under Section 220ZZ and 220ZZA of the FM Act have been applied to determine the significance of the impact.

Scheduled matters that are relevant to the Snowy 2.0 Main Works aquatic ecology assessment (including those listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), are listed in **Section 9.3**. Any key threatening process listed in Schedule 6 have been identified and assessed.

Another objective of the FM Act is to conserve key fish habitat (KFH). KFH is defined in sections 3.2.1 and 3.2.2 of the *Policy and Guidelines for Fish Conservation and Management* (Fairful, 2013) (refer **Section 3.6.1**). These are defined as aquatic habitats that are important to the sustainability of recreational and commercial fishing industries, the maintenance of fish populations generally and the survival and recovery of threatened aquatic species. In freshwater systems, most permanent and semi-permanent rivers, creeks, lakes, lagoons, billabongs, weir impoundments and impoundments up to the top of the bank are considered KFH. Small headwater creeks and gullies that flow for a short period after rain and farm dams on such systems are excluded, as are artificial water bodies except for those that support populations of threatened fish or invertebrates. At a broad scale, KFH relevant to the project includes the following:

> Permanently flowing rivers and creeks including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether or not the channel has been physically modified;

> Intermittently flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether or not the channel has been physically modified; and

> Any waterbody if it is known to support or could be confidently expected (based on predictive modelling) to support threatened species, populations or communities listed under the FM Act.

3.3 *Biosecurity Act (2015)*

The *Biosecurity Act 2015* came into effect on 1 July 2017 and provides a consolidated regulatory framework to effectively respond to and manage biosecurity risks. The broad objectives for biosecurity in NSW are to manage biosecurity risks from animal and plant pests and diseases, weeds and contaminants through a flexible and responsive statutory framework for the benefit of the NSW economy, environment and community.

A number of aquatic pests and diseases are notifiable under Schedule 1 of the *Biosecurity Regulation 2017* including redfin perch (*Perca fluviatilis*) and epizootic haematopoietic necrosis virus (EHNV) of fish.

Biosecurity risks associated with the project are discussed in **Section 7.2**.

3.4 *Biodiversity Conservation Act (2016)*

The *Biodiversity Conservation Act 2016* (BC Act) contains provisions for the conservation of some aquatic species and communities except for those listed under the FM Act (i.e. fish, crayfish and all other aquatic animals, but not freshwater vegetation). Potential impacts of the project to entities covered under the BC Act are assessed in the Biodiversity Development Assessment Report – appended to the Snowy 2.0 Main Works EIS (EMM 2019a).

3.5 Commonwealth *Environment Protection and Biodiversity Conservation Act (1999)*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) protects nationally and internationally important flora, fauna, ecological communities and heritage places, which are defined in the EPBC Act as Matters of National Environmental Significance (MNES). Under the EPBC Act, an action will require approval from the Minister for the Environment and Energy if the action has, will have, or is likely to have, a significant impact on MNES and for Commonwealth agencies, the environment generally. *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (DoE, 2013) have been developed to assist proponents in deciding if a referral to the Australian Department of Environment and Energy (DoEE) would be required. The referral process involves a decision on whether or not the action is a 'controlled action'. When an action is declared a controlled action, approval from the Commonwealth Minister for the Environment is required. Snowy Hydro referred Snowy 2.0 Main Works to the Commonwealth Minister for the Environment and nominated that Snowy 2.0 Main Works has potential to have a significant impact on MNES and the environment generally. On 5 December 2018, the Snowy 2.0 Main Works were determined to be a controlled action.

A search of the Commonwealth's protected matters search tool (PMST) was used to generate a list of MNES or other matters protected by the EPBC Act likely to occur within the study area (**Annexure A**). The extent of the search area is shown in **Annexure A** and aimed to be conservative in that it covers a significant buffer beyond the project area to encompass all waterways potentially connected to the project area and beyond. The results of the search as they relate to aquatic ecology are summarised in **Table 3-1**.

Table 3-1 MNES under the EPBC Act

MNES	Matters Relevant to Snowy 2.0 Aquatic Ecology
Commonwealth listed threatened species	Three threatened fish species and or their habitat are **known** to occur within the study area: Macquarie perch (*Macquaria australasica*) listed as 'endangered'; Murray cod (*Maccullochella peelii*) listed as 'vulnerable'; and Silver perch (*Bidyanus bidyanus*) listed as 'critically endangered' Two threatened fish species or species habitat **likely** to occur within the study area: Flathead galaxias (*Galaxias rostratus*) (also known as beaked minnow, flat-headed galaxias, flat-headed jollytail, flatheaded minnow) listed as 'critically endangered'; and Trout cod (*Maccullochella macquariensis*) listed as 'endangered'. One threatened fish species or species habitat **may occur** within the study area: Australian grayling (*Prototroctes maraena*) listed as 'vulnerable'.

3.6 Policies and Guidelines

3.6.1 Policy and Guidelines for Fish Habitat Conservation and Management

The NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013) (Fairful, 2013) are applicable to all planning and development proposals and various activities that affect freshwater ecosystems. The aims of the updated policy and guidelines are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species in freshwater environments. The updated policy and guidelines assist developers, their consultants and government and non-government organisations to ensure their actions comply with legislation, policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed or offset. The policies and guidelines outlined in this document are taken into account when NSW DPI assesses proposals for developments and other activities that affect fish habitats. The document contains:

> Background information on aquatic habitats and fisheries resources of NSW, and for determining their value in the event offsetting is required;
> An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitats in NSW;
> General policies and classification schemes for the protection and management of fish habitats and an outline of the information that NSW DPI requires to be included in development proposals that affect fish habitat;
> Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers;
> Specific policies and guidelines for foreshore works and waterfront developments; and
> Specific policies and guidelines for the management of other activities that affect waterways.

One of the objectives of the FM Act is to conserve KFH and NSW DPI focuses the application of the FM Act and FM Regulations and the policies and guidelines on KFH. It is important to note that aquatic habitats within first and second order gaining streams, sections of stream that have been concrete-lined or piped (excluding waterway crossings) and artificial ponds are not regarded as KFH unless they support a listed threatened species, population or ecological community or critical habitat. Categorisation and classification of KFH is achieved by determining fish habitat sensitivity (Type) and functionality (Class). The term 'sensitivity' refers to the importance of the habitat to the survival of fish and its ability to withstand disturbance while 'functionality' refers to the ability to provide habitat that is suitable for fish.

Fish habitat 'Type' is used within the policy and guidelines to differentiate between permissible and prohibited activities or developments and for determining value in the event offsetting is required. Waterway 'Class' is used to assess the impacts of certain activities on fish habitats in conjunction with 'Type'. The waterway 'Class' can also be used to make management recommendations to minimise impacts on different fish habitats (e.g. waterway crossings). Sensitivity 'Types' and waterway 'Class' classifications are provided in **Section 3.7** and have been used to classify waterways in the study area.

3.6.2 Why Do Fish Cross the Road? Fish Passage Requirements for Waterway Crossings

NSW DPI (Fisheries) *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull & Witheridge, 2003) provides practical guidelines for the planning, design, construction and maintenance of waterway crossings aimed at minimising impacts on fish passage and aquatic ecology in general. It should be used in conjunction with the *Policy and Guidelines for Fish Conservation and Management* (Fairful, 2013) by outlining potential impacts of instream structures and design specifications and recommendations for crossings to avoid erecting barriers to fish passage.

3.7 Key Fish Habitat

The classification of key fish habitat (KFH) type in the study area was determined using the criteria in Fairful (2013) for freshwater habitat (refer **Table 3-2**). The waterway Class was determined using the criteria in **Table 3-3**.

Table 3-2 Classification of KFH in freshwater according to sensitivity. Adapted from Table 1 in NSW DPI (Fairful, 2013)

Classification	Habitat Type
Type 1 – highly sensitive KFH	▪ Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 millimetres in two dimensions, snags greater than 300 mm in diameter or 3 m in length, or native aquatic plants; ▪ Any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the FM Act; and ▪ Mound springs.
Type 2 – Moderately sensitive KFH	▪ Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in type 1; and ▪ Weir pools and dams up to full supply level where the weir or dam is across a natural waterway.
Type 3 – Minimally sensitive KFH	▪ Freshwater habitats not included in Types 1 or 2; and ▪ Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation.
Not considered KFH	▪ First and second order gaining streams (based on the Strahler method of stream ordering); ▪ Farm dams on first and second order streams or unmapped gullies;

Classification	Habitat Type
	▪ Agricultural and urban drain; ▪ Urban or other artificial ponds (e.g. evaporation basins, aquaculture ponds; and ▪ Sections of stream that have been concrete-lined or piped (not including a waterway crossing)

Table 3-3 Classification of waterways for fish passage criteria. Adapted from Tables 2 and 3 (Fairful, 2013

Classification	Characteristics of waterway type	Minimum recommended crossing type	Additional design information
Class 1 – Major fish habitat	Marine or estuarine waterway or permanently flowing or flooded freshwater waterway (e.g. river or major creek), habitat of a threatened or protected fish species or 'critical habitat'.	Bridge, arch structure or tunnel.	Bridges are preferred to arch structures.
Class 2 – Moderate fish habitat	Non-permanently flowing (intermittent) stream, creek or waterway (generally named) with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Freshwater aquatic vegetation is present. type 1 and 2 habitats present.	Bridge, arch structure, culvert(1) or ford.	Bridges are preferred to arch structures, box culverts and fords (in that order).
Class 3 – Minimal fish habitat	Named or unnamed waterway with intermittent flow and sporadic refuge, breeding or feeding areas for aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or other Class 1 - three fish habitats.	Culvert(2) or ford.	Box culverts are preferred to fords and pipe culverts (in that order).
Class 4 – Unlikely fish habitat	Waterway (generally unnamed) with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools post rain events (e.g. dry gullies or shallow floodplain depressions with no aquatic flora present).	Culvert(3), causeway or ford.	Culverts and fords are preferred to causeways (in that order).

(1) High priority given to the 'High Flow Design' procedures presented for the design of these culverts—refer to the "Design Considerations" section of Fairfull and Witheridge (2003). (2) Minimum culvert design using the 'Low Flow Design' procedures; however, 'High Flow Design' and 'Medium Flow Design' should be given priority where affordable — refer to the "Design Considerations" section of Fairfull and Witheridge (2003). (3) Fish friendly waterway crossing designs possibly unwarranted. Fish passage requirements should be confirmed with NSW DPI.

3.8 Key Threatening Processes

A key threatening process (KTP) is a process that threatens, or may have the capability to threaten, the survival or evolutionary development of a species, population or ecological community. KTPs of relevance to aquatic ecology are listed under the FM Act, BC Act and the EPBC Act. Broadly, KTPs include threats to threatened species, populations and ecological communities as well as those that cause species, populations or ecological communities to become threatened. Of these KTPs, six have potential to be triggered by Snowy 2.0 Main Works. These include:

> Degradation of native riparian vegetation along NSW water courses (FM Act);

> Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act) and alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands (BC Act);

> Introduction of fish to waters within a river catchment outside their natural range (FM Act);

> Removal of large woody debris from New South Wales rivers and streams (FM Act);

> Land clearance (EPBC Act);

> Loss and degradation or native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act);

> Novel biota and their impact on biodiversity (EPBC Act); and

> Predation by the plague minnow (*Gambusia holbrooki*) (BC Act).

4 Approach to Impact Assessment

4.1 Overview

Key steps in undertaking the impact assessment involved:

> Review of existing information;
> Identification of Snowy 2.0 Main Works activities and impacts;
> Assessment of impacts;
> Qualitative risk assessment;
> Assessments of significance for threatened species and / or ecological communities; and
> Mitigation and management of identified activities.

4.2 Review of Existing Information

4.2.1 Publicaly Available Databases

Key sources of information, literature and publicly available databases were searched for records of listed threatened aquatic species, populations and communities within Talbingo Reservoir, Tantangara Reservoir and throughout the study area. Details are in Section 3 of Annexure B.

4.2.2 Specialist Reports Prepared for the EIS

Specialist reports have been prepared for Snowy Hydro and used to inform this AEA. The specialist reports reviewed as part of the AEA are listed in **Table 4-1**.

Table 4-1 Specialist reports prepared on behalf of Snowy Hydro reviewed as part of the AEA

Author & Date (see reference list for full citation)	Title	Purpose
Lintermans (2019)	A review of fish information from the upper Murrumbidgee and Upper Tumut catchments.	Collate and describe known and inferred distributions of fish in the study area.
Cardno (2019)	Talbingo and Tantangara reservoirs Physical Limnology.	Description of existing physical processes (e.g. stratification) within the Talbingo and Tantangara reservoirs.
(Zukowski & Whiterod, 2019)	The status of Murray crayfish in Talbingo Reservoir, 2019	Field surveys within Talbingo Reservoir in June 2019 including at sites sampled previously 2008 to 2018.
Ning et al. (2019)	Predicting invasive fish survival through the Snowy 2.0 pumped hydro scheme.	Laboratory experiments and modelling aimed at determining the expected rate of survival of redfin perch and eastern gambusia through Snowy 2.0. Survival associated with, shear stress, changes in pressure, blade strike and their combined effect were assessed. A qualitative assessment regarding the likelihood of entrainment of each species was also undertaken
Hick et al. (2019)	Assessment of the potential for increased distribution of EHNV associated with Snowy 2.0	Review of the current knowledge of EHNV in Australia with reference to Snowy 2.0.
EnviroDNA (2017)	Determining the presence or absence of invasive *Perca fluviatilis* (redfin) at Tantangara Reservoir using environmental DNA	Survey for redfin perch in Tantangara Reservoir using environmental DNA (eDNA)
EnviroDNA (2019a)	Fish and decapod environmental DNA biodiversity surveys in the Snowy 2.0 project area	Use of multi species eDNA metabarcoding techniques to investigate the presence of fish and decapod species in Talbingo Reservoir,

Author & Date (see reference list for full citation)	Title	Purpose
		Tantangara Reservoir and several watercourses within the study area.
EnviroDNA (2019b)	Determining the presence of *Perca fluviatilis* , *Gambusia holbrooki* , *Galaxias brevipinnis* and *Macquaria australasica* across a range of locations within the Snowy 2.0 project area using environmental DNA.	Use of targeted single species assay to investigate the distribution of key species of fish within selected locations in the study area.
Raadik (2018)	Identification of galaxiid species (Teleostei, Galaxiidae) within Snowy 2.0 project area	Collection and morphological examination to determine the identification of specimens of galaxiids caught within the study area.
Raadik (2019)	Tantangara Creek fish barrier design criteria – Snowy 2.0 Project.	Provision of expert advice regarding the optimal location and design criteria for a fish barrier on Tantangara Creek
Baumgartner *et al*. (2017)	Fish transfer risk associated with Snowy 2.0.	Literature review to examine the potential for transfer, survival and establishment of redfin perch in Tantangara and other species outside their current range due to Snowy 2.0..
THA Aquatic (2019)	Review of Options to Prevent the Entrainment of Redfin (*Perca fluviatilis*) at the Proposed Snowy 2.0 Pumped Hydro-electric Generation Plant	Review of physical and behavioural options to prevent the entrainment and transfer of redfin perch and an assessment of their potential suitability for use at Snowy 2.0.
Allan and Lintermans (2019)	Current Ecological Knowledge of the Critically Endangered Stocky Galaxias, *Galaxias tantangara.*	Review of available data on stocky galaxias

4.2.3 Field Surveys

Targeted field surveys were undertaken to inform aspects of the AEA and to characterise aquatic flora and fauna within the study area, with a focus on locations expected to be directly disturbed by Snowy 2.0 Main Works. Survey locations included Talbingo Reservoir, Tantangara Reservoir, and other key watercourses upstream and downstream of these reservoirs and in the upper Eucumbene River Catchment.Details of the survey methodology and results are in **Annexure B**.

The locations of survey sites are in **Figure 4-1** to **Figure 4-3** for Talbingo Reservoir, Tantangara Reservoir and other catchments.

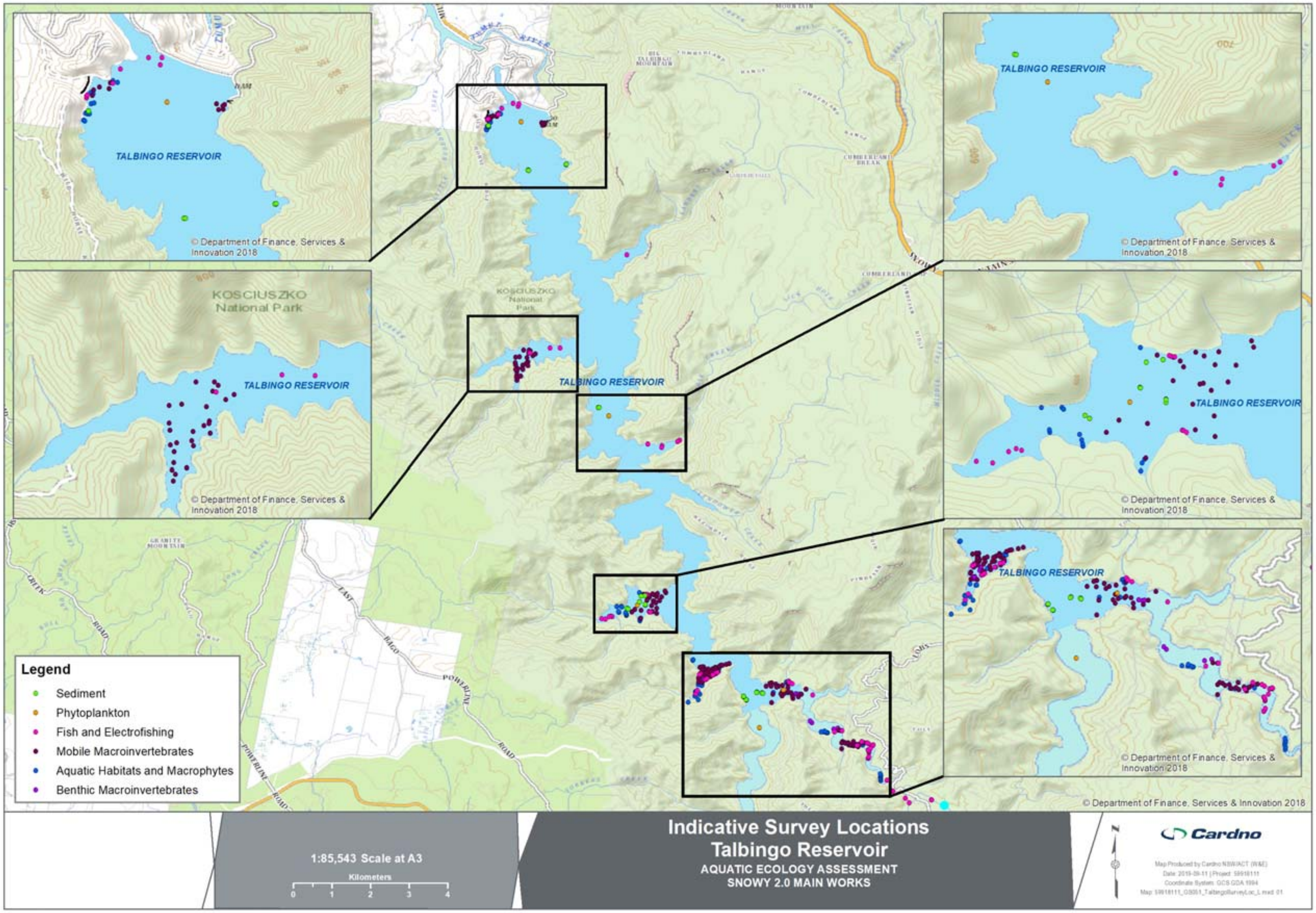

Figure 4-1 Location of field surveys undertaken in Talbingo Reservoir

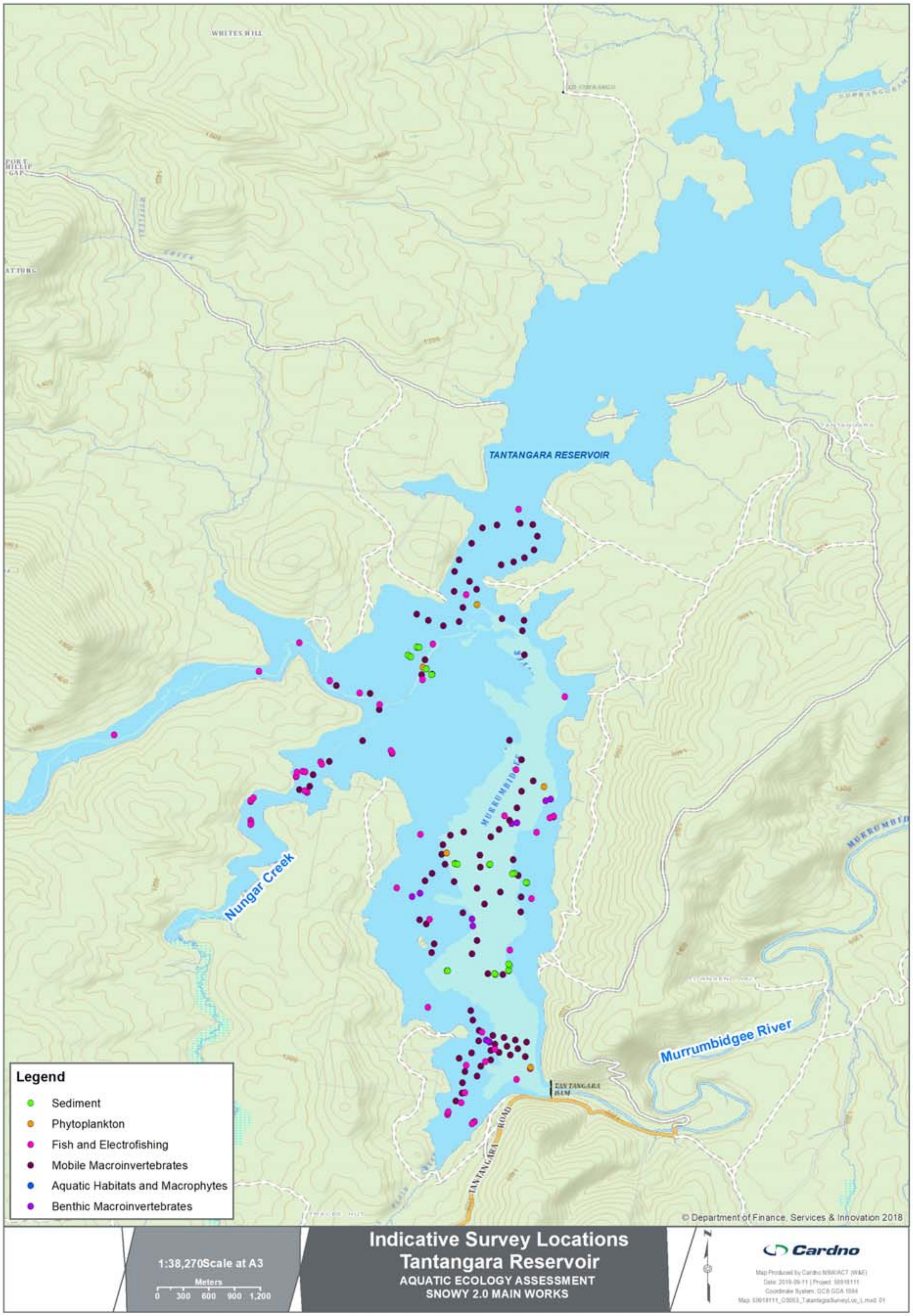

Figure 4-2 Location of field surveys undertaken in Tantangara Reservoir

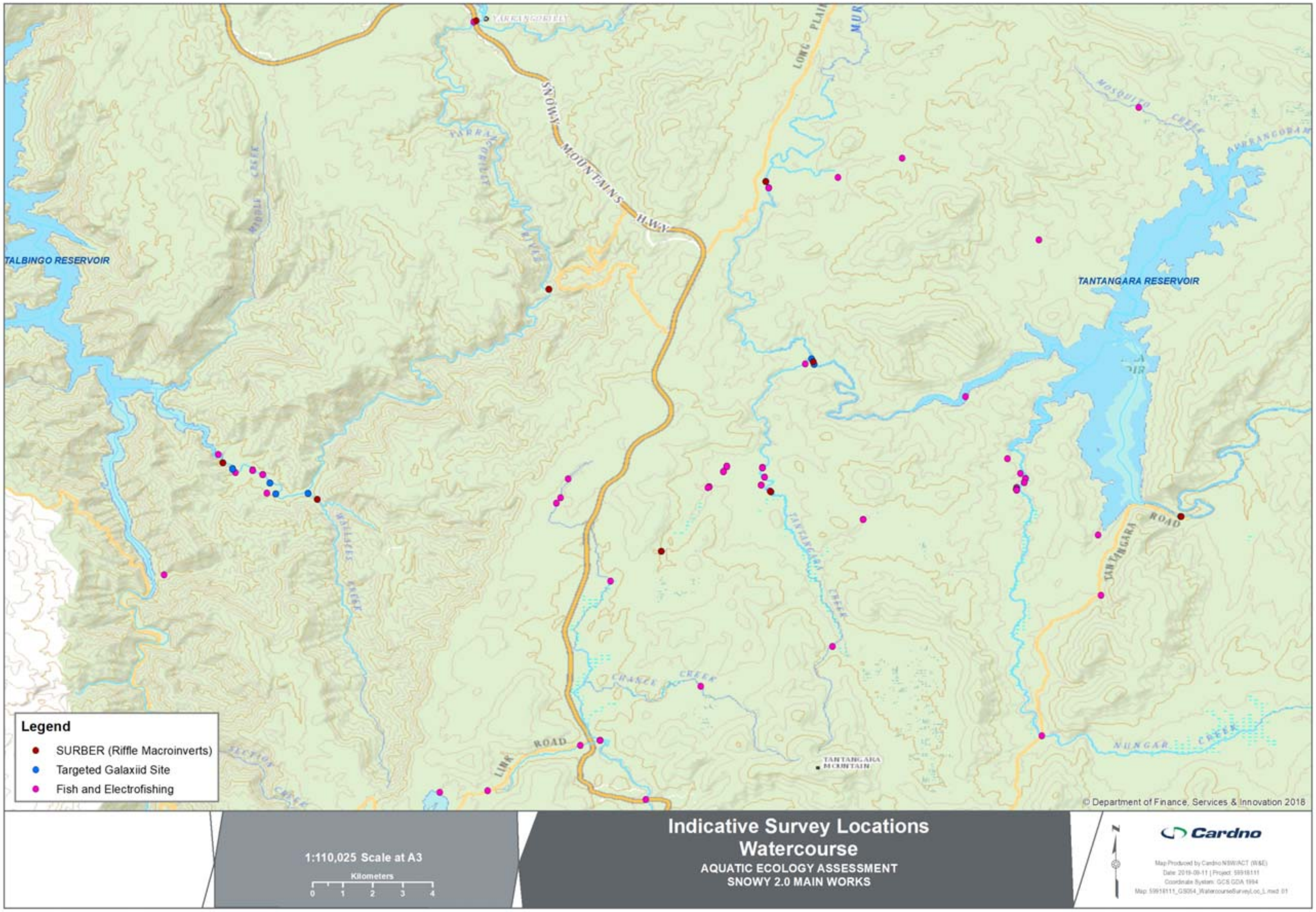

Figure 4-3 Location of field surveys undertaken in watercourses within the study area

4.3 Identification of Activities and Impacts

An environmental impact is defined as a potential action or process that may cause a change in the environment. The first stage of the impact assessment was to define the activities and/or processes associated with the project and identify the potential environmental impacts related to each activity and how they may interact cumulatively. The project activities that were assessed as part of the project Main Works included the construction, operation and rehabilitation activities described in **Section 2**. This included consideration of cumulative impacts.

The possible geographic extent of each activity and associated impact was determined at a reservoir and catchment scale and delineated according to **Figure 1-2**. Assessments were based on the possible extent of impacts, considering the best available information at the time of preparation. This included:

> Construction methodologies (Chapter 2 and Appendix D of the EIS);

> Detailed modelling of sediment plumes and sedimentation associated with placement of dredge material and material excavated from tunnelling (RHDV 2019a, b);

> Sediment and water quality testing (Appendix J, EMM, 2019a);

> Mapping of surface infrastructure and utilities (Chaper 1, EMM 2019a);

> Specialist studies relating to the transfer of water and associated biota **Section 1.6**, **Table 4-1**; and

> Operational conditions as per the project description **Section 2.3**.

Potential impacts are further identified as having 'direct', 'indirect' or 'direct' and 'indirect' impacts, and/or cumulative impacts (i.e. where multiple impacts of a particular activity may have a different or additive effect).

4.4 Assessment of Impacts and Mitigation

The potential impacts of project activities were evaluated according to an understanding of the project, modelled predictions of environmental changes that would result from the project and knowledge of the receiving habitats and biota in the study area (as per literature review and dedicated field surveys).

Measures to avoid, minimise and, control/manage identified impacts on aquatic receptors have been outlined for each project activity and associated impact. This may include additional features of the project design that were added to specifically mitigate impacts of the project, construction methodology (as outlined in the EIS, long term operational factors and/or ongoing monitoring and adaptive management strategies that would be outlined in specific management plans.

4.5 Risk Assessment

A qualitative risk assessment was carried out to identify potential risk levels associated with each project activity, both before and after implementation of the proposed mitigation and management measures. The risk assessment process was based on the Australian and New Zealand Standard guidelines for risk management (AS/NZS 4360:2004) and the *Handbook for Environmental Risk Management – Principles and Process (HB 203:2006)* (Standards Australia, 2006) which is considered an international benchmark in standard risk management. 'Risk' is defined as the chance of something happening that will have an impact on objectives (or receptors). It is measured in terms of consequences and their likelihood. Risk in the environmental context should be thought of as the environmental consequences of a given severity and the likelihood of that particular consequence occurring (AS/NZS 4360: 2004).

The risk analysis comprises an assessment of the level of consequence and likelihood of negative environmental impacts on aquatic ecosystems occurring for each activity. Assessments were based on the possible extent of impacts, considering the best available information at the time of preparation and included:

> Proposed construction methodologies as outlined in the project description (**Section 2**);

> Modelling of sediment dispersion and sedimentation associated with sub-aqueous edge placement;

> Sediment and water quality testing;

> Mapping of surface infrastructure and utilities;

> Specialist studies including the surface water and groundwater assessments; and

> Operational conditions.

Potential impacts are further identified as having a 'direct', 'indirect' or 'direct and indirect' impacts. For each activity, a risk assessment has been undertaken for the impacts associated with that activity on those receptors identified in **Table 4-2**. This has been undertaken for each reservoir and catchment expected to be affected (according to catchment definitions in **Table 1-1** and **Figure 1-2**). For some activities and impacts, this may include multiple catchments, for others these were restricted to a single reservoir/catchment.

The likelihood of receptors occurring within each reservoir and / or catchment was determined according to the criteria outlined in (**Table 4-6**) and based on findings from the literature review and field surveys. Further details of the species biology and ecology and detailed results of field surveys are in **Annexure B**. Where a receptor is a threatened species, individual species and associated risks to that individual species were identified. Native species were assessed as a group, with the risk assessment based on the impact of an activity on the most vulnerable native species of those known to occur in the reservoir/catchment. Planktonic assemblages were also assessed as a group and it was assumed that they would occur in all reservoirs and catchments across the study area. The definitions associated with determining the consequence for each activity is outlined in **Table 4-4**. Likelihood and consequence were then combined into a matrix to provide a high level qualitative assessment of overall risk for each activity and associated impact on key receptors (**Table 4-5**). Risk levels were identified as low, moderate, high or extreme (**Table 4-5**). This determination does not mean that the project should not proceed (i.e. if the level of risk is high) or that an issue should be ignored if the level of risk is considered low, but rather that the issue may need a greater level of management and / or mitigation, offsetting, monitoring or further research as appropriate.

Risk assessments were not undertaken where the likelihood that threatened or native aquatic species occurring within a catchment was considered to be 'absent' or 'low' as per **Table 4-6**. The likelihood and consequence of impacts to salmonids was assessed but a risk rating was not provided as these species are non-native and hence negative impacts to these species would not be considered detrimental from an ecological perspective. In this instance, the overall risk rating was denoted as N/A. Similarly, potentially negative impacts to redfin perch and other pest species (e.g. eastern gambusia), were not assessed as they would not be detrimental to native aquatic biota.

Table 4-2 Receptors identified in the risk assessment

Receptor	Description
Threatened aquatic species	Aquatic species listed under the FM Act or EPBC Act with a moderate or greater likelihood of occurrence in a particular catchment
Native aquatic species	Other aquatic species with moderate or greater likelihood of occurrence in a particular catchment
Salmonids	Includes recreationally important brown trout, rainbow trout, brook trout and Atlantic salmon
Planktonic assemblages	Phytoplankton and/or zooplankton

Table 4-3 Qualitative measures of likelihood of an impact occurring

Likelihood	Description
Almost Certain	Impact expected to occur as a result of the project.
Likely	Impact will probably occur as a result of the project
Possible	Impact could occur as a result of the project
Unlikely	Impact would probably not occur as a result of the project
Rare	Impact not expected to occur as a result of the project.

Table 4-4 Qualitative measures of consequence adjusted to the scale and duration of the impact

Consequence	Description
Catastrophic	Permanent extinction of a species No recovery predicted
Major	Permanent loss of a population (regionally or genetically isolated) does not result in extinction of a species. No recovery predicted.
Moderate	Permanent adverse change to an existing population (e.g. abundance, demographics and/or structure). Although population viability is maintained, it may not recover to pre-existing conditions
Minor	Temporary adverse changes to existing population with recovery to pre-existing conditions
Insignificant	Changes to the population within natural variability

Table 4-5 Risk matrix (after AS/NZS 4360:2004). This is applicable to native species only.

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low	Moderate	High	Extreme	Extreme
Likely	Low	Moderate	High	High	Extreme
Possible	Low	Moderate	Moderate	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Rare	Low	Low	Moderate	Moderate	Moderate

Risk Rating	Actions required
Extreme	Despite all practical and feasible methods being implemented the risk remains unmanageable. These risks should be avoided where possible.
High	Significant measures for management and control are required to manage risks and prevent further impacts. If uncontrolled these risks may have a substantial adverse impact on aquatic ecology.
Moderate	Routine and/or specific management activities required to reduce or manage risk. Risk is manageable.
Low	All reasonable care taken (e.g. training, environmental awareness etc.) to manage the risk. Risks should be recorded, monitored and controlled.

Table 4-6 Criteria used to assess the likelihood of fish and crayfish species occurring in reservoirs and / or catchments within the study area.

Likelihood of occurrence	Code	Criteria or Evidence for Assessment of Occurrence
Low	**Low (X):**	Area within historical distribution with sporadic recent records (stocking or catch records), expert opinion and/or negative DNA detection or field survey results suggest species is not currently present.
	Low (P):	Within predicted distribution, however, strong evidence to suggest it is not currently present (based on expert opinion and/or negative DNA detection or field survey results; or
	Low (DNA):	DNA detected*, but unlikely to represent live fish (due to low relative abundance of DNA and / or low detection rate combined with the absence of previous records (for known recreationally targeted species) and none caught during current field surveys). DNA may be from inert source of material from outside the reservoir/catchment. Includes potential landlocked populations of catadromous fish (e.g. *Anguilla* spp.)
Moderate	**Mod (Adj):**	No recent records in the reservoir/catchment but suitable habitat is present (DPI 2016a) with no barriers to movement from adjacent areas of known occurrences; or
	Mod (P):	Within predicted distribution range (DPI 2016a), but no confirmed catch records. (A precautionary approach has been applied and a medium likelihood of occurrence used where the species cannot be categorised as absent or of low occurrence (see above).
Occurs	**Oc (X):**	Species recently recorded or stocked in the catchment and the catchment provides suitable habitat.

Likelihood of occurrence	Code	Criteria or Evidence for Assessment of Occurrence
	Oc (DNA)	DNA of a species detected and the area is within the currently expected species distribution. Recent records may not be available for non-recreationally important species.
	Oc (C)	Caught during current study.
	Oc (X +DNA)	Combination of Oc (X) and Oc (DNA) .
	Oc (X+C+DNA)	Combination of Oc (X), Oc (DNA) and Oc (C)

*DNA detections at low relative abundance (≤ 1 % relative abundance) reported by EnviroDNA (2019a) represent a low likelihood of occurrence of live individuals in the absence of historical catch records or catches during project field surveys.

The following assumptions and rationale are applicable to the risk assessment process:

> Potential impacts were identified through a combination of specialist advice, modelling, literature review and stakeholder consultation;

> The categories for environmental consequences are based on duration and spatial scale of potential impacts;

> The risk analysis identifies the relative significance of risks with and without proposed mitigation (e.g. implementation of environmental management plans for project elements). Any mitigation or management not already inherent in the project design and/or project description were not considered in the 'before' mitigation assessment;

> Although some risks are considered to be 'low', further action may be recommended (through routine procedures) as appropriate;

> No weighting was applied which would place a greater importance on any one of the consequence criteria alone, or in combination:

> It was assumed that plankton (zooplankton and phytoplankton) occur across all reservoirs and catchments within the study area:

> Potential impacts to salmonids in terms of their importance as a recreationally fished species is addressed in the Social Impact Assessment Report (Appendix X.2 – EMM 2019a);

> A construction phase of 6 years and operational phase of 100 years has been assumed; and

> Only potential impacts outside the current approved operation of Talbingo and Tantangara reservoirs were assessed.

Apart from the receptors identified within the qualitative risk framework presented above, there was also a need to identify and assess impacts that may be associated with KFH and EEC as distinct from the biota occurring there. In such cases where an impact to either or both of these has been predicted, the spatial and/or temporal extent of the impact was identified relative to its unaffected amount, its potential for recovery and consideration of offsets as per Fairful (2013).

5 Existing Environment

5.1 Snowy Hydro Scheme

The Snowy Scheme is situated within a large geographical region comprising lakes and watercourses interconnected by natural and artificial water bodies (**Figure 5-1**). At this large scale, it also connects the south and westward flowing Murray Darling River system with eastward-flowing waters to the Pacific Ocean via the catchment of the Snowy River.

5.1.1 Existing Connectivity

The existing Snowy Hydro Scheme was constructed to enable the transfer of water from the Snowy River catchment to the Murrumbidgee River and Murray River catchments to provide water for agriculture. The scheme also took advantage of changes in altitude to generate electricity using hydro-electric power stations. To meet these objectives, impoundments (primarily Lake Eucumbene and Lake Jindabyne) were constructed to intercept water in the upper Snowy River Catchment. Artificial connections were constructed to transport water from one or both of these impoundments via two major pathways:

> From Lake Eucumbene to the upper Tumut River via Tumut Pond Reservoir and Tumut 2 Pondage. From there water flows through the associated Tumut 1 and Tumut 2 power stations into Talbingo Reservoir, Jounama Pondage and Blowering Reservoir into the lower Tumut River and thence into the Murrumbidgee River. Water is also transferred to the upper Tumut River from the upper Murray River catchment. This occurs via a direct transfer from Tooma Reservoir (on the Tooma River) to Tumut Pond Reservoir; and

> From Lake Eucumbene and Lake Jindabyne to the upper Murray River via Geehi Reservoir on the Geehi River, through Murray 1 power station to Murray 2 Pondage, through Murray 2 power station to Khancoban Pondage, the Swampy Plain River and ultimately the Murray River. Water can be transferred to Jindabyne Reservoir from the upper Murray River Catchment via Geehi Reservoir.

Water from the upper Murrumbidgee River Catchment is transferred from Tantangara Reservoir to Lake Eucumbene through the unidirectional Murrumbidgee-Eucumbene tunnel. Water from the Goodradigbee River also enters the system via the Goodradigbee River Aqueduct into Tantangara Reservoir (and is unidirectional).

Thus, there is currently a one-way transfer of water from Tantangara Reservoir to the Upper Murray River and the Upper Tumut River Catchment (including Talbingo Reservoir). There is currently no connection that allows water from Talbingo Reservoir to enter Tantangara Reservoir. Snowy 2.0 would establish two-way connection between Talbingo Reservoir and Tantangara Reservoir, enabling water from Talbingo Reservoir to enter the Murrumbidgee River, Snowy River, and Murray River catchments (**Figure 5-1**). It would also provide a more direct route for transfer of water from Tantangara Reservoir to Talbingo Reservoir via the proposed new, underground power station. The Snowy River catchment upstream of Island Bend Dam wall (including Island Bend Reservoir, Guthega Reservoir and Blue Lake), Tooma Reservoir in the upper Murray River Catchment and Happy Jacks Pondage in the upper Tumut River Catchment do not receive water from these pathways. This would not change as a result of Snowy 2.0.

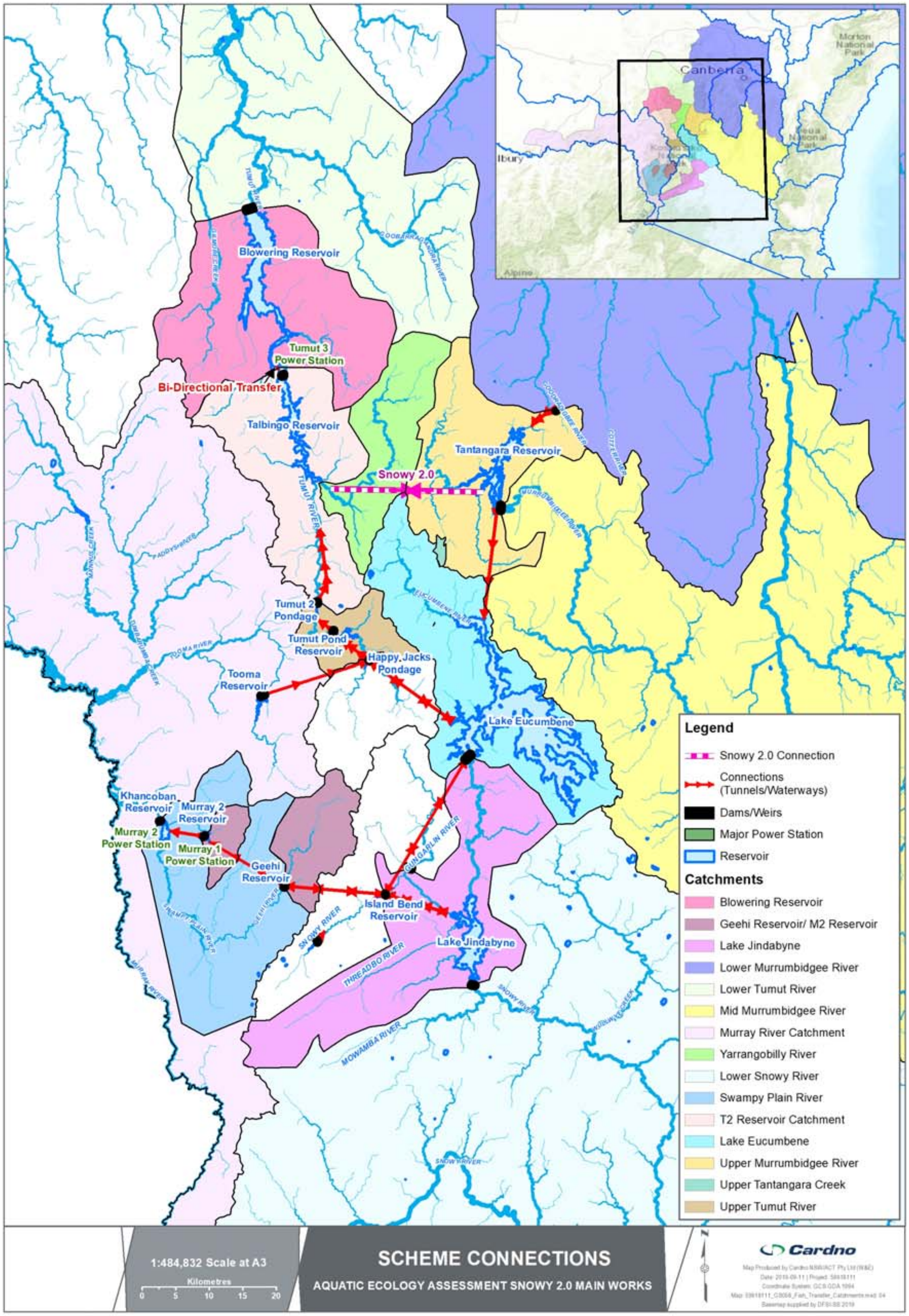

Figure 5-1 Current and proposed (Snowy 2.0) hydrological connections and major impoundments, barriers (dams and weirs) in the study area, overlaid with catchment boundaries. Arrows indicate direction of hydrological connectivity.

5.2 Climate and Weather

The physical limnology report (Cardno 2019) provides a description of the climate and weather associated with the study area.

5.3 Talbingo Reservoir

5.3.1 Overview of Reservoir

Talbingo Reservoir is located on the Tumut River, approximately seven kilometres upstream of the town of Talbingo. The reservoir captures water released from Tumut 2 (T2) power station and create a head storage for the operation of the Tumut 3 (T3) pump-storage project. Water discharged from T3 can also be pumped back into the reservoir from Jounama Pondage which is located immediately downstream of Talbingo Reservoir (refer Figure 5-1). Once water is released from Jounama Pondage, it enters Blowering Reservoir where it is released by WaterNSW. Talbingo Reservoir also receives water from natural catchment inflows, with the Tumut River and Yarrangobilly River both forming the main catchment inflow into the reservoir. Smaller creeks, such as Honeysuckle Creek, Long Creek, Glendowner Creek and Middle Creek also flow into the reservoir and contribute to its natural catchment inflows. The reservoir has a gross storage volume of 920 GL of water (at 100% capacity) and at its maximum depth it reaches approximately 140 m below the dam crest. The reservoir covers an area of 19.36 km^2 and has a catchment area of 1,093 km^2. Further details about the existing features and operation of the reservoir including the hydrology and thermal structure can be found in the Talbingo and Tantangara Physical Limnology Report (Cardno 2019).

5.3.2 Water Quality

Water quality characteristics of Talbingo Reservoir are as follows:

> pH ranges between 6.3 and 8.2, with occasional lower and upper bound exceedances;
> Low concentrations of suspended solids and low turbidity;
> Carbonate and salinity vary seasonally, with higher levels occurring in summer/autumn, correlating with the higher salinity of streamflow over summer and autumn months;
> Oxidised nitrogen concentrations exceeded Water Quality Objectives (WQO) frequently in winter/spring and occasionally in summer/autumn. This is the opposite trend to the Yarrangobilly River, were exceedances are more likely to occur in summer/autumn;
> Ammonia concentrations frequently exceed WQO values during winter/spring, correlating with the elevated oxidised nitrogen;
> Total phosphorus concentrations exceed WQO values in all summer/autumn samples and in approximately 25% of winter/spring samples;
> All dissolved metal concentrations were below WQO values except:
  - copper and zinc concentrations exceeded WQO values frequently in summer/autumn and occasionally in winter/spring; and
  - chromium (total) and lead concentrations occasionally exceeded WQO values in summer/autumn.

It is noted that all but one of the copper and zinc exceedances occurred during March 2018 sampling, where 80% of samples exceeded the WQO values. Different methods of analysis (consistent with the methods applied more broadly to EIS sampling) were applied to subsequent sampling (post-March 2018).

Reservoir water quality during and following wet weather conditions is poorly understood. There is potential for elevated turbidity, nutrients and some metals to occur near watercourse inflow locations for several weeks following a substantial runoff event. Further details are available in the Water Assessment Report – Appendix J (EMM 2019a).

5.3.3 Sediment Quality

Throughout Talbingo Reservoir, sediments sampled by Cardno (refer **Figure 4-1**) and described by RHDHV (2018) were broadly classified as soft and muddy, fine textured predominantly consisting of course silts. Close to the dam wall sediments generally consist of a homogenous layer of brown to grey hydrous silt assumed to have been deposited following construction. In close proximity to the proposed intake structure in the Yarrangobilly River, gravelly sand overlaying brown to grey silts are present. Residual clay deposits with varying composition of sand and gravel are present in Cascade Bay, Plain

Creek Bay and Ravine Bay. Within these deposits, roots and a thin layer of darker coloured sediments are also present.

The concentrations of a variety of metals within sediments collection throughout Talbingo Reservoir were predominantly below National Assessment Guidelines for Dredging (NAGD) screening levels and Interim Sediment Quality Guideline (ISQG) low values provided in ANZECC / ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. The concentrations of nickel at sites throughout Talbingo reservoir and the concentrations of copper at a limited number of sites within the reservoir exceeded guidelines. Dilute acid extraction testing indicates that the concentrations of copper and nickel were below the NAGD screening levels suggesting these metals are unlikely to be bioavailable and likely pose a low risk to the environment (RHDHV, 2018).

Since the flooding of the Tumut and Yarrangobilly river valleys in 1971, the average rate of sediment deposition throughout the reservoir has been estimated to be approximately 2 mm per year. The average rate of sedimentation near Middle Bay has been estimated to be approximately 15 mm per year and potentially higher further upstream. The higher rate of sedimentation at Middle Bay compared with other areas throughout the reservoir is likely the result of relatively higher flow rate/velocity and sediment flux (bed load and suspended sediment load) down the unregulated Yarrangobilly River. Once flows from the Yarrangobilly River discharge into the reservoir the water velocity would be expected to decrease and suspended sediments settle out of suspension. Of relevance to the project is the inferrence that benthic organisms are adapted to the current rates of sedimentation, with higher sedimentation near the locations of water inflow. The key consideration for the AEA is the horizontal and vertical extent of sedimentation due to emplacement and the physico-chemical composition of the emplacement materials.

5.3.4 Aquatic Habitats and Plants

The following major aquatic habitats have been identified within the reservoir:

> Unvegetated soft sediment;
> Aquatic macrophytes;
> Submerged timber;
> Rocky rubble; and
> Open Water.

Details of the survey methodology can be found in **Annexure B**.

Submerged macrophytes and algae were observed at most locations examined within Talbingo Reservoir. Species recorded included:

> *Elodea canadensis* (Canadian pondweed - *Elodea*) (non-native);
> *Potamogeton ochreatus* (blunt pondweed);
> *Potamogeton crispus* (curly pondweed); and
> *Nitella sp*. (nitella)

In addition, the emergent macrophyte*, Phragmites australis*, was observed in the reservoir, just downstream of the mouths of the Yarrangobilly and Tumut rivers.

5.3.5 Fish and Crayfish

Based on the findings of the literature review, field surveys and eDNA data, the list of threatened, native and non-native aquatic fish and crayfish species with their likelihood of occurrence of Moderate or above in Talbingo Reservoir are provided in **Table 5-1**. Further details of the literature review and field surveys can be found in **Annexure B**.

Table 5-1 Threatened, native and non-native aquatic species and their likelihood of occurrence in Talbingo Reservoir.

	Scientific Name	Common Name	Likelihood of occurrence
Threatened Species			
Percichthyidae	*Maccullochella macquariensis*#	Trout cod FM & EPBC Acts: End.)	Oc (X)

	Scientific Name	Common Name	Likelihood of occurrence
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X+C+DNA)
Non-threatened Native Species			
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X+DNA)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (DNA)
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Mod (Adj)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (DNA)
Parastacidae	*Cherax* spp.	Common yabby	Oc (C+DNA)
Atyidae		Freshwater glass shrimp	Oc (DNA)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+C+DNA)
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X+C+DNA)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X+C+DNA)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+C+DNA)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+C+DNA)

Key: Vul. = Vulnerable, End. = Endangered. For details of Likely Occurrence, see **Table 5-6**.

[#]A stocking program for trout cod is currently being undertaken within Talbingo Reservoir. There is no evidence that a self sustaining population occurs here.

5.3.6 Benthic Macroinvertebrates

Sampling of benthic macroinvertebrates within Talbingo Reservoir yielded 2,252 individuals from 10 taxonomic groups (Family level or higher) in 34 samples. Oligochaete worms (relatives of earthworms) were the most numerically abundant, accounting for 81% and 79% of all individuals collected from the reservoir in March 2018 and January 2019, respectively. Other prominent taxa within the reservoir included nematode worms and chironomids (insects). Further details of the literature review and field surveys can be found in **Annexure B**.

Mean taxon richness of benthic infauna (i.e. number of taxa sampled) was generally low within Talbingo Reservoir for both surveys, with fewer than four Families recorded at most locations sampled. No clear pattern of spatial variability in benthic invertebrate assemblages was apparent. For further details on the methodology used and detailed description of the results see **Annexure B**.

5.3.7 Plankton

Phytoplankton data have been collected by Snowy Hydro within reservoirs associated with the Snowy Hydro Scheme, including Talbingo Reservoir, as part of an ongoing monitoring program since 1998 (multiple times per year) and include data on total phytoplankton levels and key phytoplankton taxa (e.g. *Cyanophytes* (blue-green algae), *Bacillariophyceae* (diatoms), *Chlorophyta* (green algae), *Chrysophyceae* (golden algae), *Cryptophyceae*, *Euglenophyta* and *Pyrrophyta)*.

These data indicate that phytoplankton counts within Talbingo Reservoir have generally been below 3,000 cells/mL throughout much of the monitoring program, although they exceeded 5,000 cells/mL on a number of occasions (see **Annexure B**). Most notably, mean phytoplankton levels within the reservoir were in excess of 10,000 cells/mL on two occasions during the monitoring period, one each in the spring of 2002 and 2007.

Total nitrogen (TN) and total phosphorus (TP) levels can significantly influence and increase phytoplankton abundance. Mean TN values were always below the (ANZECC / ARMCANZ, 2000) Default Trigger Values (DTV) for south-east Australia freshwater lakes and reservoirs during the monitoring program, whereas mean TP values exceeded the DTV on a number of occasions. From the data, it does not appear that the patterns observed in phytoplankton abundance within Talbingo Reservoir correlate to any great extent with the nutrient data although the resolution of the data may not account for smaller temporal and spatial scale patterns that may be present for both phytoplankton abundance and nutrient levels (see **Annexure B**).

The long term data set indicates that the composition of phytoplankton assemblages within Talbingo Reservoir generally consists of chlorophytes (45%), cyanophytes (38%) and bacillariophytes (15%), with these three taxa groups providing over 98% of the taxon composition of phytoplankton within the reservoir during the monitoring period (**Annexure B**).

5.3.7.1 Field Surveys

Surface water samples (taken between 0 m and 3 m depth) were collected from Talbingo Reservoir by Cardno to examine the small-scale spatial and temporal variability and taxonomic resolution of phytoplankton assemblages. Details of the field survey, data analysis and results regarding phytoplankton sampling undertaken are provided in **Annexure B**.

Phytoplankton assemblages did not vary statistically among locations during each sampling event, indicating a relatively homogeneous phytoplankton assemblage between 0 m and 3 m in the reservoir for each month sampled. Significant temporal differences in phytoplankton assemblage structure were identified between sampling events with phytoplankton abundance significantly greater in June compared with March and May. The number of phytoplankton taxa was similar between March and May, although a significant decrease in the number of taxa was detected between May and June 2018. Thus, there were fewer taxa but larger cell counts identified in June 2018.

In summary, there appears to be a significant seasonal influence on phytoplankton assemblages within Talbingo Reservoir, however, very little spatial difference in assemblage structure was apparent within any sampling event.

5.3.8 Key Fish Habitat

Talbingo Reservoir is classified as a type 1 KFH because of the presence of Murray crayfish there (see also definitions in **Table 3-2**) (NSW DPI, 2019a).

5.3.9 Pathogens

Based on the NSW Aquatic Pest and Disease Distribution map, *Lernaea* spp. (anchor worms) are suspected/anecdotally considered present and EHNV, an Australian type of iridovirus, is confirmed to be present in the Murrumbidgee River catchment (see **Annexure B** for more information). Neither anchor worms nor EHNV have been recorded within Talbingo Reservoir.

5.4 Tantangara Reservoir

5.4.1 Overview of Reservoir System

Tantangara Reservoir is on the Murrumbidgee River, approximately 50 km upstream from Adaminaby with much of it situated within a flat, alpine plateau. The current purpose of the reservoir is to impound the headwaters of the Murrumbidgee River for diversion through the Murrumbidgee-Eucumbene Tunnel to Lake Eucumbene for storage. Water from the Goodradigbee River, a downstream tributary of the Murrumbidgee River, is also diverted to the reservoir via the Goodradigbee River Aqueduct. Tantangara Reservoir receives water from natural catchment inflows, mainly from the Upper Murrumbidgee River, Nungar Creek and Mosquito Creek. The reservoir has a gross capacity of 254 GL, a surface area of 21.17 km^2 and a catchment area of 460 km^2. Further details about the existing features and operation of the reservoir including the hydrology and thermal structure can be found in the Talbingo and Tantangara Physical Limnology Report (Cardno 2019).

5.4.2 Water Quality

Water quality characteristics of Tantangara Reservoir are as follows

> pH ranges between 6.6 and 8.0, with one lower and upper bound exceedance occurring;

> Low levels of suspended solids and low turbidity;

> Carbonate and salinity vary seasonally, with higher levels occurring in summer/autumn;

> Oxidised nitrogen and ammonia occasionally exceeded WQO values in summer/autumn;

> Total phosphorus frequently exceeded WQO values in summer/autumn and winter/spring while reactive phosphorus occasionally exceeded WQO values;

> All dissolved metal concentrations were below WQO values except for:

- aluminium concentrations frequently exceeded WQO values;
- copper, iron and zinc frequently exceeded WQO values during summer/autumn; and
- chromium (total), cobalt and lead occasionally exceeded WQO values during summer/autumn.

All copper and zinc exceedances occurred during the March 2018 survey, where every sample exceeded its WQO for Cu and Zn. Different analysis methods (consistent with the methods applied more broadly to EIS sampling) were applied to subsequent sampling (post-March 2018).

Reservoir water quality during and following wet weather conditions is poorly understood. There is potential for elevated turbidity, nutrients and some metals to occur near locations of watercourse inflow for several weeks following a substantial runoff event. Further details are available in the Water Assessment Report (Appendix J, EMM 2019a).

5.4.3 Sediment Quality

Sediment from throughout Tantangara Reservoir was soft and muddy, fine textured and predominantly consisting of coarse silt (0.02-0.075 mm) with a smaller varying fractions of clay (<0.002 mm). Heavy metal concentrations (for those for which there are available guidelines are) were within guidelines at all sites sampled.

The sedimentation rates in Tantangara Reservoir are estimated to be 0 mm to 3 mm per year (RHDHV, 2018). RHDHV noted that reservoir sediment deposits are typically thinner between FSL and MOL. Deposits in shallower water would be readily remobilised by nearshore waves and currents (wind generated waves or boat wash) and deposited in deeper water. As the water level in the reservoir is periodically lowered, sediment deposits near the shoreline would be expected to be re-mobilised into deeper water and lead to shoreline erosion.

5.4.4 Aquatic Habitats and Plants

Aquatic habitats in Tantangara Reservoir consist primarily of:

> Unvegetated soft sediment;

> Drowned grass tussocks and shrubs;

> Rocky rubble;

> Rock boulders and emergent bedrock; and

> Open water.

Details of the survey methodology can be found in **Annexure B**. *Elodea* was the only species of macrophyte recorded in Tantangara Reservoir although it was recorded on one occasion at one location.

5.4.5 Fish and Crayfish

Based on the findings of the literature review, field surveys the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of moderate or above in Tantangara Reservoir are provided in **Table 5-2**. Further details of the literature review and field surveys can be found in **Annexure B**. No threatened species were detected or considered likely to occur within the reservoir.

Table 5-2 Threatened, native and non-native aquatic species and their likelihood of occurrence in Tantangara Reservoir

	Scientific Name	Common Name	Likelihood of occurrence*
Non - Threatened Species			
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (DNA)
Parastacidae	*Cherax* spp.	Common yabby	Oc (C+DNA)
Parastacidae	*Euastacus reiki*	Reik's crayfish	Oc (DNA)
Non-Native Species			
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+C+DNA)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+C+DNA)

* See **Table 5-6** for explanation of Likelihood of Occurrence

5.4.6 Benthic Macroinvertebrates

Sampling of benthic macroinvertebrates within Tantangara Reservoir yielded 4,768 individuals from 12 taxonomic groups (Family level or coarser) in 34 samples. Oligochaete worms, Chironomids (non-biting midges) and nematode worms accounted for over 95% of benthic invertebrates sampled. No clear pattern in the spatial variability of benthic invertebrate assemblages within Tantangara Reservoir was apparent.

For further details on the methodology used and detailed description of the results see **Section 3** of **Annexure B**.

5.4.7 Plankton

Snowy Hydro have been sampling phytoplankton data in Tantangara Reservoir since 1998 (multiple times per year). The abundance of phytoplankton within Tantangara Reservoir has increased somewhat since 2010, often exceeding 7,000 cells/mL during this period. In Autumn 2010, Spring 2012 and Autumn 2013, mean phytoplankton counts exceeded 15,000 cells/mL. Prior to 2010, average phytoplankton counts within the reservoir were generally less than 5,000 cells/mL (**Annexure B**). Phytoplankton abundance within the reservoir did not correlate with the concentration of total nitrogen or total phosphorus, which is consistent with findings from Talbingo Reservoir.

This long term data set indicates that the composition of the phytoplankton assemblage within Tantangara Reservoir generally consists of cyanophytes (44%), cyanophytes (19%) and bacillariophytes (30%). Similar to the results for Talbingo Reservoir over 90% of the phytoplankton assemblage within Tantangara Reservoir consist of these three groups (**Annexure B**).

5.4.7.1 Field Surveys

Surface water samples (between 0 m and 3 m depth) were collected from Tantangara Reservoir by Cardno to examine small-scale spatial and temporal variability of phytoplankton assemblages. Further details of field survey, analysis and results regarding phytoplankton sampling undertaken is in **Annexure B**.

Broadly, as recorded in Talbingo Reservoir, phytoplankton assemblages did not vary significantly among locations within the reservoir during each sampling event, suggesting a relatively homogeneous phytoplankton assemblage within the reservoir. Temporal differences in phytoplankton assemblages were, however, detected. No significant changes in the number of phytoplankton taxa within Tantangara Reservoir throughout the sampling period were detected.

5.4.7.2 Zooplankton

It is understood no specific information is available on zooplankton assemblages within Tantangara Reservoir. Like phytoplankton, zooplankton form the basis of many food webs and, as such, have an important role in maintaining reservoir ecosystems.

5.4.8 Key Fish Habitat

Tantangara Reservoir is mapped as KFH in the Snowy River (NSW DPI, 2019b) KFH maps prepared by NSW DPI (Fisheries). Based on further field surveys and existing information, Tantangara Reservoir is considered a type 2 KFH (moderately sensitive fish habitat) because no threatened or protected species are known to occur there and because it is a freshwater lake not defined as a type 1 habitat (as per Fairfull and Witheridge 2003).

5.4.9 Pathogens

Based on the NSW Aquatic Pest and Disease Distribution map, *Lernaea* spp. (anchor worms) are suspected/anecdotally considered present and EHNV is confirmed to be present in the Murrumbidgee River catchment. See **Annexure B** for more information.

Neither anchor worms nor EHNV have been recorded in Tantangara Reservoir.

5.5 Catchments

5.5.1 Overview of Catchments

An overview map of catchments is provided in **Figure 1-2** and **Figure 5-1**. General descriptions in terms of location, connectivity within the study area and aquatic species found in each catchment are described below. A complete summary of threatened, non-threatened native and non native fish and invertebrates and their likelihood of occurrence across reservoirs and/or catchments throughout the study area is provided in **Annexure B**.

5.5.2 Tumut 2 Reservoir Catchment

5.5.2.1 General Description

The Tumut Two (T2) Reservoir catchment includes the Tumut River upstream of Tumut 2 Pondage, including Tumut Pond Reservoir, Tumut River and tributaries upstream to Happy Jacks Pondage dam wall. The main tributaries in this catchment include Clear Creek, Fifteen Mile Creek and Nine Mile Creek. The catchment is relatively undisturbed, consisting of extant vegetation, grassy woodlands and grasslands (Bevitt, et al., 2009). This section of the Tumut River is considered to be a type 1 – highly sensitive KFH.

5.5.2.2 Fish and Crayfish

Based on the findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Tumut Two Reservoir Catchment are provided in **Table 5-3**. See **Annexure B** for more information. Other than a limited amount of eDNA sampling, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-3 Threatened, native and non-native aquatic species and their likelihood of occurrence in the T2 Reservoir Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Parastacidae	*Cherax* spp.	Common yabby	Oc (X)
Non-Native Species			
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)
Salmonidae	*Salvelinus fontinalis*	Brook trout	Oc (X)

Key: Vul. = Vulnerable, End. = Endangered, Crit. End. = Critically Endangered
* See **Table 5-6** for explanation of codes

5.5.3 Upper Tumut River Catchment

5.5.3.1 General description

The upper Tumut River catchment includes the Tumut River below Tumut 2 Reservoir dam wall and all other tributaries flowing into Talbingo Reservoir upstream of FSL. It does not include the Yarrangobilly River arm of Talbingo Reservoir which has been considered as a separate (Yarrangobilly River) catchment for the purpose of this assessment. The major tributaries in this catchment include the Tumut River (which flows northwards into the southern end of Talbingo Reservoir), Long Creek, Glendower Creek, Lickhole Creek, Honeysuckle Creek and Landers Creek. The catchment surrounding Talbingo Reservoir is generally undisturbed, consisting of native, dry sclerophyll forest (Brevitt et al., 2009). The Tumut River flows southward from the Tumut 2 Reservoir dam wall to where it flows into Talbingo Reservoir. The land along this stretch of the Tumut River consists of a corridor of mostly undisturbed grassy woodland (Bevitt, et al., 2009) and assessed as type 1 – highly sensitive KFH.

5.5.3.2 Fish and Crayfish

Based on the findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Upper Tumut River Catchment are provided in **Table 5-4**.

Table 5-4 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Upper Tumut Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Maccullochella macquariensis*#	Trout cod FM & EPBC Acts: End.)	Mod (Adj)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Mod (Adj)
Non-threatened Native Species			
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Mod (Adj)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Mod (Adj)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Mod (Adj)
Parastacidae	*Cherax* spp.	Common yabby	Mod (Adj)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+DNA)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)

* See **Table 5-6** for explanation of codes

5.5.4 Yarrangobilly River Catchment

5.5.4.1 General description

The Yarrangobilly River starts approximately 22 km east of Talbingo, flowing generally to the south-west, turning west at the Yarrangobilly Village campground and Jounama Trail, where it crosses beneath the Snowy Mountains Highway. Following this, it continues south until it meets the following tributaries: Wallaces Creek, Cave Gully, Lick Hole Gully and Sheep Station Creek where it turns north-west. As it runs north-west, it flows into Talbingo Reservoir. The substratum of the perennial Yarrangobilly River and Wallaces Creeks has potential to provide spawning habitat for native fish and trout as it includes boulders, cobbles and gravel, and healthy riparian vegetation.

The river meanders throughout the catchment, with rocky outcrops, pools and riffles. The surrounding terrain typically comprises subalpine grasslands, woodlands and montane dry sclerophyll forests, although some vegetation has been cleared around the Yarrangobilly campground and where Cave Gully meets the Yarrangobilly River (Brevitt et al., 2009). The catchment is relatively undisturbed and considered of high ecological value (EMM, 2018). No artificial or significant natural barriers to fish passage were identified on the sections of Yarrangobilly River and Wallaces Creek surveyed. Yarrangobilly River and Wallaces Creek support type 1 – highly sensitive KFH due to the presence of large rocks, large wood debris (in Yarrangobilly River) and the provision of habitat for a threatened species (Murray crayfish) in both watercourses.

Tributaries of Wallaces Creek (Lick Hole Creek and Sheep Station Creek), are ephemeral with limited instream habitat. These watercourses are classified as type 3 – minimally sensitive KFH, due to their highly ephemeral flow and the absence of native aquatic plants. Results of field studies carried out within the Yarrangobilly River Catchment are in **Annexure B**.

5.5.4.2 Fish and Crayfish

Based on findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Yarangobilly River Catchment are provided in **Table 5-5**. Further detail is provided in **Annexure B**.

Table 5-5 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Yarrangobilly River Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Maccullochella macquariensis***	Trout cod FM & EPBC Acts: End.)	Mod (Adj)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X+C+DNA)
Non-threatened Native Species			
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X+DNA)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (X+C+DNA)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Mod (Adj)
Parastacidae	*Cherax* spp.	Common yabby	Mod (Adj)
Parastacidae	*Euastacus* sp.***	Unidentified spiny crayfish**	Oc (DNA)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+C+DNA)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+C+DNA)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+C+DNA)

* See Table 5-6 for explanation of codes
** A stocking program for trout cod is currently being undertaken into Talbingo Reservoir
*** Three species of *Euastacus* are known to occur within the study area (Morgan 1997; Shull et al. 2005 in EnviroDNA 2019a) and therefore it is proposed that this DNA detection, which does not correspond to Reik's crayfish or Murray crayfish may, correspond to alpine spiny crayfish. However, no idividuals were caught during the field survey and taxonomy cannot be resolved at the time of writing.

5.5.5 Blowering Reservoir Catchment

5.5.5.1 General Description

The Blowering Reservoir Catchment encompasses the area immediately north (downstream) of Talbingo Reservoir dam wall and the Tumut 3 Power Station to Jounama Pondage and Blowering Reservoir. The catchment is bounded in the north by the Blowering Reservoir dam wall. Jounama Pondage is located immediately downstream of Talbingo Reservoir dam wall and continues north for approximately 2.8 km. Water released from Talbingo Reservoir, is held in Jounama Pondage before being released to Blowering Reservoir via a small hydro station or gated spillway. Blowering Reservoir stores water from the Snowy-Tumut Development for subsequent release downstream to the Murrumbidgee irrigation areas. Surface area of the reservoir is approximately 44.6 km^2. Tributaries draining into Blowering Reservoir are the Sandy River, Log and Log Bridge Creeks, Ryans, Blowering and Janeys Creeks. A large portion of the catchment is forested and undisturbed, particularly on the western side, whereas much of the eastern side has been cleared or grazed. The Snowy Mountains Highway also runs along the eastern side of the reservoir. The reservoir is assessed as type 1 KFH due to the known occurrence of threatened species (see below).

5.5.5.2 Fish and Crayfish

Based on findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Blowering Reservoir catchment are provided in **Table 5-6**. Other than a limited amount of eDNA sampling in Jounama Reservoir, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-6 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Blowering Reservoir Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)	Oc (X+DNA)
Percichthyidae	*Bidyanus bidyanus*	Silver perch (FM Act: Vul.)	Oc (X)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Percichthyidae	*Macquaria ambigua*	Golden perch	Oc (X+DNA)
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X+DNA)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (X+DNA)
Parastacidae	*Cherax* spp.	Common yabby	Oc (DNA)
Parastacidae	*Engaeus cymus*	Burrowing crayfish	Oc (X)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+DNA)
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (DNA)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (DNA)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+DNA)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+DNA)

* See Table 5-6 for explanation of codes

5.5.6 Lower Tumut River Catchment

5.5.6.1 General description

The Lower Tumut River Catchment is defined by the Tumut River north (downstream), of Blowering Reservoir and power station. Below the Blowering Reservoir dam wall it flows north for approximately 42 km where it converges with the Murrumbidgee River. Major tributaries include the lower portion of Gilmore Creek and the Goobarragandra River. The catchment includes mostly agricultural land with the town of Tumut and forested Werebolda State Conservation Area located in the south-west portion of the catchment. Because of the occurrence of threatened species in this catchment it is classed a type 1 KFH.

5.5.6.2 Fish and Crayfish

Based on findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Lower Tumut River catchment are provided in **Table 5-7**. No field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-7 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Lower Tumut River Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Macquaria australasica*	Macquarie perch (FM & EPBC Acts: End.)	Oc (X)
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)	Mod (Adj)

	Scientific Name	Common Name	Likelihood of occurrence*
Percichthyidae	*Bidyanus bidyanus*	Silver perch (FM Act: Vul.)	Mod (Adj)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Percichthyidae	*Macquaria ambigua*	Golden perch	Oc (X)
Percichthyidae	*Gadopsis marmoratus*	(Northern) River blackfish	Oc (X)
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (X)
Eleotridae	*Hypseleotris* spp.	Carp gudgeon	Oc (X)
Parastacidae	*Cherax* spp.	Common yabby	Mod (Adj)
Parastacidae	*Euastacus crassus*	Alpine spiny crayfish	Oc (X)
Parastacidae	*Engaeus cymus*	Burrowing crayfish	Oc (X)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X)
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X)
Cyprinidae	*Cyprinus carpio*	Carp	Oc (X)
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)

Key: Vul. = Vulnerable, End. = Endangered, Crit. End. = Critically Endangered
* See **Table 5-6** for explanation of codes

5.5.7 Upper Murrumbidgee River Catchment

5.5.7.1 General description

The Upper Murrumbidgee River Catchment extends from the upper alpine areas of KNP and includes the Upper Murrumbidgee River and all other tributaries of Tantangara Reservoir up to FSL. Major tributaries within the catchment include Nungar Creek, Tantangara Creek (up to Tantangara Creek Waterfall just upstream of the Alpine Creek Trail), Gooandra Creek and Mufflers Creek to the west of the reservoir, Mosquito Creek at the north and Kelly's Plain Creek at the south. The major watercourses to the west of the Upper Murrumbidgee River Catchment are generally perennial and flow through alpine environments with a mixture of native and non-native sedges, grasses and shrubs. Tantangara Creek and Gooandra Creek are generally narrower and shallower than the Murrumbidgee River and flow over a mixture of cobble, pebble and gravel substrata with some boulders, bedrock and deeper pool sections. Nungar Creek has a similar geomorphology to Tantangara Creek and a greater proportion of gravel and sand substratum.

Aquatic habitat in the catchment includes areas of shallow riffles and deeper pools with widths of up to 10 m. Native aquatic vegetation (*Potamogeton tricarinatus* and *Myriophylum* sp.) occur in isolated patches in Tantangara and Gooandra creeks and the Murrumbidgee River, and most of the smaller tributaries. Large rocks and gravel beds are also present.

The Murrumbidgee River, Tantangara Creek (and tributary TCA1/2), Gooandra Creek, Nungar Creek, Bally Creek and Ghost Gully provide type 1 – highly sensitive KFH, due to the presence of native aquatic plants and large rocks and are classified as Class 1 waterways due to their perennial flow. The remaining watercourses provide type 2 – moderately sensitive KFH. The pools associated with Gooandra Creek, Tantangara Creek and Nungar Creek are type 3 KFH. Further details and results of field surveys within this catchment are in **Annexure B**.

5.5.7.2 *Fish and Crayfish*

Based on the findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Upper Murrumbidgee River Catchment are in **Table 5-8**. No threatened species were detected or considered likely to occur within this catchment.

Table 5-8 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Upper Murrumbidgee River Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Non-threatened Native Species			
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (C+DNA)
Parastacidae	*Cherax* spp.	Common yabby	Oc (DNA)
Parastacidae	*Euastacus reiki*	Reik's crayfish	Oc (X+C+DNA)
Non-Native Species			
Salmonida	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+C+DNA)

* See **Table 5-6** for explanation of codes

5.5.8 Upper Tantangara Creek Catchment

5.5.8.1 *General Description*

The Upper Tantangara Creek catchment is a relatively small area, encompassing only a 4 km stretch of Tantangara Creek upstream of its confluence with Boggy Plain Creek. Several, small, unnamed and ephemeral tributaries also enter this section of Tantangara Creek as it flows northwards. A small track crossing and waterfall are located in this catchment. The waterfall is significant, as it represents the downstream limit of the distribution for the threatened stocky galaxias. Stocky galaxias are not known to occur downstream of the waterfall (or anywhere else) presumably due to the presence of trout which are known to prey on galaxias. Thus the waterfall facilitates an upstream refuge for the entire known population of this species. The creek habitat above the waterfall consists generally of riffle and pool habitat with the substratum predominantly bedrock, boulders and cobble with small sections of pebble, gravel and silt (**Annexure B**). The land use in this area is relatively undisturbed with a narrow corridor of riparian vegetation and grassland, with grassy woodland beyond. This section of Tantangara Creek is a type 1 – highly sensitive KFH due to the known presence of the stocky galaxias.

5.5.8.2 *Fish and Crayfish*

Based on the findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of moderate or above in the Upper Tantangara Creek Catchment are provided in **Table 5-9**. No field surveys were undertaken within this catchment.

Table 5-9 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Upper Tantangara Creek Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Galaxiidae	*Galaxias tantangara*	Stocky galaxias (FM Act: Crit. End.)	Oc (X)
Non-threatened Native Species			
Parastacidae	*Euastacus reiki*	Reik's crayfish	Mod (Adj)

* See **Table 5-6** for explanation of codes

5.5.9 Mid Murrumbidgee River Catchment

5.5.9.1 General description

The Mid Murrumbidgee River Catchment is part of the Murrumbidgee River Catchment and extends from below Tantangara Reservoir dam wall to the ACT/NSW border. The primary watercourses in this catchment include the Murrumbidgee River and the Numeralla River. The Murrumbidgee River runs for approximately 190 km from the Tantangara Reservoir dam wall to the ACT border in this catchment. The Numeralla River extends for approximately 110 km from its headwaters to the Mid Murrumbidgee River.

Within this catchment, the Murrumbidgee River flows from Tantangara Reservoir in a general south-east direction, turning north at Binjura, meeting the Numeralla River near Chakola and proceeding to the NSW/ACT border crossing at Gigerline Nature Reserve.

The habitat from the dam wall, south to Yaouk is generally undisturbed grassland and grassy woodland. Downstream of Yaouk there are large sections of cleared land until the Binjura Nature Reserve in the southern part of the catchment where the channel becomes deeply incised and surrounded by undisturbed native sclerophyll forest. As the Murrumbidgee River flows north again towards Bredbo the land is largely cleared for agricultural purposes and partly urbanised along the Monaro Highway. Beyond this the area directly to the west of the river consists of wet sclerophyll forest and patchy dry sclerophyll forest before reaching the Gigerline Nature Reserve (Keith & Simpson, 2006).

This catchment is within the Snowy-Monaro LGA, and is generally zoned as E1 National Parks and Nature Reserve and RU1 Primary Production with the exception of town areas and infrastructure. The Murrumbidgee River downstream of Tantangara Reservoir dam wall provides type 1 KFH. This is due to the presence of large rocks, wood debris, native aquatic plants and the presence of threatened Macquarie perch (known at least as far downstream as Yaouk Bridge). Results of field studies within the Mid Murrumbidgee River Catchment are in **Annexure B**.

5.5.9.2 Fish and Crayfish

Based on findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Mid Murrumbidgee River Catchment are provided in **Table 5-10**. Other than limited eDNA sampling at the upstream end of this catchment, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-10 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Mid Murrumbidgee River Catchment.

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Macquaria australasica*	Macquarie perch (FM & EPBC Acts: End.)	Oc (X+DNA)
Percichthyidae	*Maccullochella macquariensis*#	Trout cod FM & EPBC Acts: End.)	Oc (X)
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)	Oc (X)
Percichthyidae	*Nannoperca australis*	Southern pygmy perch (FM Act: End.)	Mod (P)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Percichthyidae	*Macquaria ambigua*	Golden perch	Oc (X)
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X+C+DNA)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (X)
Eleotridae	*Hypseleotris* spp.	Carp gudgeon	Oc (X)

	Scientific Name	Common Name	Likelihood of occurrence*
Parastacidae	*Cherax* spp.	Common yabby	Oc (X+C+DNA)
Parastacidae	*Euastacus reiki*	Reik's crayfish	Oc (X)
Palaemonidae	-	Freshwater prawn	Oc (DNA)
Atyidae	*Paratya australiensis*	Freshwater glass shrimp	Oc (DNA)
Non-Native Species			
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X+DNA)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X+DNA)
Cyprinidae	*Cyprinus carpio*	Carp	Oc (X+DNA)
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+C+DNA)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+C+DNA)

* See **Table 5-6** for explanation of codes

5.5.10 Lower Murrumbidgee River Catchment

5.5.10.1 General description

The Lower Murrumbidgee River Catchment includes the Murrumbidgee River from the northern NSW/ACT border downstream (northwards) to Lake Burrinjuck in Burrinjuck Waters State Park and extends generally as far east as Georges Lake. The Goodradigbee River is also a significant tributary which drains from just north of Tantangara Reservoir in a northerly direction until it meets Lake Burrinjuck and the Murrumbidgee River (some water from the upper section of the Goodradigbee River is also re-directed into Tantangara Reservoir). From its crossing into the ACT and on to Lake Burrinjuck, the Murrumbidgee River meanders through large areas of cleared agricultural land and several nature reserves (Bullen Range, Stoney Creek and Woodstock), and areas of forested wetland and dry sclerophyll forest (Keith & Simpson, 2006). Riparian vegetation generally occurs along the length of the river but becomes sparse at the northern end of the catchment around Lake Burrinjuck. Flow regulation along the river has degraded the health of the overall ecosystem (MDBA, 2019a). High sediment loads resulting from agricultural practices have resulted in sedimentation of the river channel and floodplain, and the supply of water for irrigation has affected the natural flow seasonality and variability (MDBA, 2019a). This catchment is assessed as significant type 1 – highly sensitive KFH, with several small ephemeral waterways of more limited ecological value.

5.5.10.2 Fish and Crayfish

Based on findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of moderate or above in the Lower Murrumbidgee River Catchment are provided in **Table 5-11**. Other than limited eDNA sampling at the upstream end of this catchment, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-11 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Lower Murrumbidgee River Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Macquaria australasica*	Macquarie perch (FM & EPBC Acts: End.)	Oc (X)
Percichthyidae	*Maccullochella macquariensis*[#]	Trout cod FM & EPBC Acts: End.)	Oc (X)
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)	Oc (X)
Percichthyidae	*Bidyanus bidyanus*	Silver perch (FM Act: Vul.)	Oc (X)

	Scientific Name	Common Name	Likelihood of occurrence*
Plotosidae	*Tandanus tandanus*	Eel-tailed catfish - Murray-Darling Basin Population (FM Act: End.)	Oc (X)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Percichthyidae	*Macquaria ambigua*	Golden perch	Oc (X)
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (X)
Eleotridae	*Philypnodon macrostomus*	Dwarf flathead gudgeon	Oc (X)
Eleotridae	*Hypseleotris* spp.	Carp gudgeon	Oc (X)
Parastacidae	*Cherax* spp.	Common yabby	Mod (Adj)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+DNA)
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X+DNA)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X)
Cyprinidae	*Cyprinus carpio*	Carp	Oc (X)
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)

* See **Table 5-6** for explanation of codes

5.5.11 Lake Eucumbene Catchment

5.5.11.1 General description

The Lake Eucumbene Catchment encompasses Lake Eucumbene, the Eucumbene River and several small tributaries (including Bullocks Head Creek, Chance Creek, Racecourse Creek, Three Mile Creek and Gang Gang Creek) and is bounded by the Lake Eucumbene dam wall to the south-west. The primary watercourse of interest to the AEA in this catchment is the upstream section of the Eucumbene River which runs for approximately 37 km south from its source in the plateau region of the study area before reaching Lake Eucumbene. Along this stretch, the Eucumbene River meanders through the KNP with pools, riffles and cobbles and boulder habitat. The surrounds generally comprise open and closed woodland or alpine tundra. Closer to the confluence with Lake Eucumbene it is fringed by dense grassy woodlands. Lake Eucumbene itself is predominantly surrounded by cleared open land, but with dense grassy woodland dominating the western side of the lake. Other than the Eucumbene River, tributaries flowing into Lake Eucumbene include Badgerys Creek in the south-east, Little Plain Creek in the north and Little Tolbar, Big Tolbar, Bald Hill. Dogtrap and Doghill Creeks in the west.

The Eucumbene River and its main tributaries are designated as type 1 KFH, due the presence of native aquatic plants and / or their association with the EEC listing for the Snowy River system, which includes these watercourses and provides endangered status to all associated species. Lake Eucumbene itself is considered a type 2 KFH (moderately sensitive fish habitat) as this area is excluded from the EEC listing, no threatened or protected species are known to occur there and because it is a freshwater lake not defined as a type 1 habitat (as per Fairful and Witheridge 2003).

Results of field studies in the Lake Eucumbene Catchment are reported in **Annexure B**.

5.5.11.2 Fish and Crayfish

Based on findings of the literature review and field surveys, no threatened fish species occurt within this catchment. Native and non-native fish and crayfish species with a likelihood of occurrence of Moderate or above in the Lake Eucumbene Catchment are listedin **Table 5-12**. No threatened species were detected or considered likely to occur within this catchment. The climbing galaxias within this catchment likely originated from the lower Snowy River and spread throught the waterways within the upper catchment created by the original Snowy Hydro Scheme.

Table 5-12 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Lake Eucumbene Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Non-threatened Native Species			
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (DNA)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (DNA)
Parastacidae	*Cherax* spp.	Common yabby	Oc (X+DNA)
Parastacidae	*Euastacus reiki*	Reik's crayfish	Oc (C+DNA)
Non-Native Species			
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X)
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+DNA)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+DNA)
Salmonidae	*Salvelinus fontinalis*	Brook trout	Oc (X+DNA)

* See **Table 5-6** for explanation of codes

5.5.12 Lake Jindabyne Catchment

5.5.12.1 General Description

The Lake Jindabyne Catchment includes Lake Jindabyne up to FSL and its tributaries, including the Eucumbene River up to the base of Lake Eucumbene dam wall, the Snowy River catchment upstream of Lake Jindabyne to Island Bend Dam Wall, Gungarlin River Catchment upstream to Burrungubugee and Gungarlin Weirs and the Thredbo River. Several tributaries join the Eucumbene River between Lake Eucumbene and Lake Jindabyne, including Pipeclay, Snowy Gap Rivulet, Rocky Plains, Bills and Bundara creeks. This section of the Eucumbene River is alpine and runs in riffle and pool sequences along the eastern border of the KNP and the Nimmo Nature Reserve, but is partly modified with large flowing sections below the dam wall.

Riparian vegetation occurs along most reaches, however, this was historically cleared in parts and replaced with non-native willows (NSW DPI, 2011). The catchment to the west of the river is densely vegetated, and to the east it is generally cleared for agriculture (stock). Natural in-stream structures, such as falls or cascades and sand bars, as well as constructed features, such as dams and weirs, have regulated natural flows thereby affecting the normal reproductive and other biological cues for biota.

A constant small environmental release is made from Eucumbene Dam to ensure visible flow is present in the river at all times. Flow control and loss of seasonal variability, and stock access to the riparian zone causing erosion and sedimentation, have degraded the overall health of the ecosystem (NSW DPI, 2011). Disturbance within the catchment includes firewood collection, degradation from feral animals (including pigs), and fire (DECCW, 2008). A fish kill was reported in the Thredbo River on 25 January 2019. It included the death of approximately 20 rainbow and brown trout and was attributed to high water temperature (DPI Website).

Smaller tributaries entering the lake include Kalkite Creek and Wollondibby Creek. The land surrounding Lake Jindabyne has mostly been cleared with the towns of Jindabyne and East Jindabyne located on the southern foreshores of Lake.

The waterways within this catchment are assessed as type 1 KFH, due the presence of native aquatic plants and / or their association with the EEC listing for the Snowy River, which includes the above watercourses and provides endangered status to all associated species.

Lake Jindabyne itself is considered a type 2 KFH (moderately sensitive fish habitat) as this area is excluded from the EEC listing, no threatened or protected species are known to occur there and because it is a freshwater lake not defined as a type 1 habitat (as per Fairfull and Witheridge 2003).

5.5.12.2 Fish, Crayfish and Dragonfly

Based on findings of the literature review and field surveys, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Lake Jindabyne Catchment are in **Table 5-13**. Other than eDNA sampling, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-13 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Lake Jindabyne Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Gadopsis marmoratus*	River blackfish – Snowy River Catchment Population (FM Act: End.)	Mod (P)
Odonata	*Austropetalia tonyana*	Alpine redspot dragonfly (FM Act: Vul.)	Mod (P)
Non-threatened Native Species			
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (DNA)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Mod (Adj)
Parastacidae	*Cherax* spp.	Common yabby	Oc (X)
Parastacidae	*Euastacus reiki*	Reik's crayfish	Oc (X)
Non-Native Species			
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X)
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)
Salmonidae	*Salmo salar*	Atlantic salmon	Oc (X)
Salmonidae	*Salvelinus fontinalis*	Brook trout	Oc (X)

Key: Vul. = Vulnerable, End. = Endangered, Crit. End. = Critically Endangered
* See **Table 5-6** for explanation of codes

5.5.13 Lower Snowy River Catchment

5.5.13.1 General description

The Lower Snowy River Catchment encompasses the Snowy River downstream (south) of Lake Jindabyne and its major tributaries including the Mowamba River and Wullwye Creek. Downstream of Lake Jindabyne the river then winds for approximately 400 km southwards until it reaches the Snowy Inlet, at Marlo, Victoria and flows into the Tasman Sea. Throughout its course, the Snowy River has 56 tributaries. From Lake Jindabyne, the river moves in a general south-easterly direction through Beloka Gorge and the Monaro Tableland past Dalgety and turning south at Ironmungy Nature Reserve 13 km downstream. The river then flows south for approximately 30 km until it reaches Meringo Nature Reserve. The Snowy River then meets the Maclaughlin and Delegate rivers, and turns north-west and west until reaching Barry Way. It then turns south into Victoria and the Tasman Sea, with the Deddick and Buchan rivers flowing into it on the way.

Approximately 75% of the Snowy River's length is protected by either the KNP in NSW or the Alpine and Snowy River National Parks in Victoria. In NSW, the river runs through the Snowy Monaro Regional

Council LGA, and in Victoria the East Gippsland LGA. The aquatic ecological community of the Snowy River catchment in NSW is listed as an endangered ecological community (EEC) (see **Section 5.6.2**). This catchment provides significant type 1 – highly sensitive KFH.

5.5.13.2 Fish and Crayfish

Based on findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Lower Snowy River Catchment are in **Table 5-14**. No field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-14 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Lower Snowy River Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Gadopsis marmoratus*	River blackfish – Snowy River Catchment Population (FM Act: End.)	Oc (X)
Percichthyidae	*Nannoperca australis*	Southern pygmy perch (FM Act: End.)	Oc (X)
Non-threatened Native Species			
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (X)
Galaxiidae	*Galaxias terenasus*	Roundsnout galaxias	Oc (X)
Galaxiidae	*Galaxias maculatus*	Common galaxias	Oc (X)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (X)
Anguillidae	*Anguilla australis*	Shortfinned eel	Oc (X)
Anguillidae	*Anguilla reinhardtii*	Longfinned eel	Oc (X)
Parastacidae	*Cherax* spp.	Common yabby	Oc (X)
Parastacidae	*Euastacus crassus*	Alpine spiny crayfish	Oc (X)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X)
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X)
Cyprinidae	*Cyprinus carpio*	Carp	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)

* See **Table 5-6** for explanation of codes

5.5.14 Murray River to Hume Reservoir Catchment

5.5.14.1 General Description

This catchment includes the Murray River from approximately the NSW/Victorian border in the south and west to the Tumbarumba Creek and Tooma Rivers (and their tributaries), in the north and including the Swampy Plains River Catchment below Khancoban Reservoir. A large portion of the catchment is cleared, with corridors of wet sclerophyll forest along the Tooma and Murray rivers and lower section of the Swampy Plain River (Keith & Simpson, 2006). This catchment provides significant type 1 – highly sensitive KFH, with several small ephemeral waterways of more limited ecological value.

5.5.14.2 Fish and Crayfish

Based on findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Murray River to Hume Reservoir Catchment are in **Table 5-15**. No field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-15 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Murray River to Hume Reservoir Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Macquaria australasica*	Macquarie perch (FM & EPBC Acts: End.)	Oc (X)
Percichthyidae	*Maccullochella macquariensis*#	Trout cod FM & EPBC Acts: End.)	Oc (X)
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)	Oc (X)
Percichthyidae	*Nannoperca australis*	Southern pygmy perch (FM Act: End.)	Oc (X)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Percichthyidae	*Macquaria ambigua*	Golden perch	Oc (X)
Percichthyidae	*Gadopsis marmoratus*	(Northern) River blackfish	Oc (X)
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X)
Galaxiidae	*Galaxias olidus*	Mountain galaxias	Oc (X)
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (X)
Galaxiidae	*Galaxias arcanus*	Riffle galaxias	Oc (X)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (X)
Eleotridae	*Philypnodon macrostomus*	Dwarf flathead gudgeon	Oc (X)
Eleotridae	*Hypseleotris* spp.	Carp gudgeon	Oc (X)
Parastacidae	*Cherax* spp.	Common yabby	Oc (X)
Parastacidae	*Euastacus crassus*	Alpine spiny crayfish	Mod (Adj)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X)
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X)
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X)
Cyprinidae	*Cyprinus carpio*	Carp	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)

* See **Table 5-6** for explanation of codes

5.5.15 Swampy Plain River Catchment

5.5.15.1 General Description

The Swampy Plain River Catchment encompasses the area downstream of the Geehi River below the Geehi Reservoir dam wall and includes Khancoban Reservoir, Swampy Plain River above the reservoir, the Geehi River and their tributaries. The catchment is comprised predominantly of undisturbed wet sclerophyll forest with an area of uncleared land around where Swampy Plain Creek that flows into Khancoban Reservoir (Keith & Simpson, 2006). The flows released from Geehi Dam are almost negligible, being only for maintenance purposes, thus the flows in the river below the dam are from groundwater and the residual catchments. Seasonal variability and high flows no longer occur (Brevitt et al., 2009). This reach of the Geehi River has alternating riffle-run sequences on low slopes and boulder / pool sequences on steeper slopes. The Geehi River has a good cover of riparian vegetation and in-stream macrophytes, however, stream health at this location is considered impaired (Brevitt et al., 2009). The Swampy Plain River rises near Mount Kosciuszko and flows east, then north towards Khancoban Reservoir. Several tributaries join Swampy Plain River between its source and Khancoban Reservoir including Wilkinsons and Bridge creeks, the Geehi River, and Walls, Devils, Mollers and Back creeks. The catchment of the Swampy Plain River is undisturbed for much of its length apart from the cleared lower section at Khancoban Reservoir. This catchment provides significant type 1 – highly sensitive KFH.

5.5.15.2 Fish, Crayfish and Dragonfly

Based on findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Swampy Plain River Catchment are in **Table 5-16**. Other than limited eDNA sampling, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-16 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Swampy Plain River Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)	Oc (X)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X)
Odonata	*Austropetalia tonyana*	Alpine redspot dragonfly (FM Act: Vul.)	Oc (X)
Non-threatened Native Species			
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X)
Galaxiidae	*Galaxias olidus*	Mountain galaxia	Oc (X)
Retropinnidae	*Retropinna semoni*	Australian smelt	Oc (X)
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Mod (Adj)
Parastacidae	*Cherax* spp.	Common yabby	Oc (X)
Parastacidae	*Euastacus crassus*	Alpine spiny crayfish	Oc (X)
Parastacidae	*Engaeus cymus*	Burrowing crayfish	Oc (X)
Non-Native Species			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+DNA)
Cyprinidae	*Cyprinus carpio*	Carp	Oc (X)
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)
Salmonidae	*Salmo salar*	Atlantic salmon	Oc (X)

* See **Table 5-6** for explanation of codes

5.5.16 Geehi Reservoir and M2 Reservoir Catchment

5.5.16.1 General Description

The Geehi Reservoir and M2 (Murray 2) catchment includes the Geehi Reservoir, the stretch of the Geehi River upstream of the Geehi Reservoir and the Smaller M2 Reservoir and catchment approximately 12 km west of Geehi Reservoir. The two reservoirs are geographically separated, but hydrologically linked via the Murray 1 power station and tunnel system. The Geehi River originates approximately 15 km upstream above Geehi Reservoir and flows southward into the Geehi Reservoir, with its main tributaries being Back Flat, Valentine and Dicky Cooper creeks. The upper section of the Geehi River is fringed by alpine heathlands and the lower section is densely forested. Based on Brevitt et al. (2009) the macroinvertebrate fauna of this river section is as expected for such a stream in its natural state and the river is considered to have good habitat (including spawning habitat) for native fish and invertebrates.

The Murray 2 Reservoir lies to the west of Geehi Reservoir and is fed by two main tributaries, Broken Back Creek and Khancoban Back Creek, and from transfers from Geehi Reservoir. It is also connected to Khancoban Reservoir via Khancoban Back Creek, which flows westward from the Reservoir. The land in the catchment is mostly undisturbed sclerophyll forest with narrow strips of cleared land between the M2 and Khancoban Reservoirs (Keith & Simpson, 2006). This catchment provides significant type 1 – highly sensitive KFH.

5.5.16.2 Fish and Crayfish

Based on findings of the literature review, the threatened, native and non-native aquatic fish and crayfish species with a likelihood of occurrence of Moderate or above in the Geehi and M2 Reservoir Catchment are provided in **Table 5-17**. Other than limited eDNA sampling, no field surveys were undertaken within this catchment as it is outside of the project area.

Table 5-17 Threatened, native and non-native aquatic species and their likelihood of occurrence in the Geehi and M2 Reservoir Catchment

	Scientific Name	Common Name	Likelihood of occurrence*
Threatened Species			
Odonata	*Austropetalia tonyana*	Alpine redspot dragonfly (FM Act: Vul.)	Mod (P)
Non-threatened Native Species			
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Oc (X)
Parastacidae	*Euastacus crassus*	Alpine spiny crayfish	Mod (Adj)
Non-Native Species			
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X)

* See **Table 5-6** for explanation of codes

5.6 Areas of Conservation Significance

5.6.1 Kosciuszko National Park

Kosciuszko National Park (KNP) is located within a variety of climatic regions that include several distinctive ecosystems. KNP covers an area of 6,900 km^2 and includes the Snowy, Murray and Tumut rivers. The general location of the KNP is in **Figure 1-1**. The Kosciuszko Independent Scientific Committee (KISC, 2004) in its aquatic values assessment states that lakes and rivers in KNP fit the definition of objects in the *National Parks and Wildlife Act* that require conservation and management. KISC (2004) concluded that these large rivers, located at 900 m above sea level, are considered endangered habitats in the Snowy Mountains region.

KISC (2004) stated in the fauna values report for the assessment of the values of KNP report that KNP is part of the central segment of the Australian bioregion supporting all the alpine endemic fauna species found on the Australia mainland. Additionally, KNP forms nearly half of the area of the Australian Alpine National Parks system (with Victoria and ACT).

5.6.2 Snowy River EEC

The aquatic ecological community of the Snowy River catchment in NSW has been listed as an endangered ecological community (EEC) under the FM Act. The listing includes all native fish and aquatic invertebrates within all rivers, creeks and streams within the EEC including the Snowy, Eucumbene, Thredbo, Gungarlin, Mowamba, Bombala, Mclaughlin, Delegate, Pinch and Jacobs rivers. It includes the riverbed channels inundated by artificial impoundments of Jindabyne, Eucumbene, Island Bend and Guthega dams, but excludes the ecological communities that have developed within the waters of these impoundments. The catchments (as delineated in **Figure 5-1**) that include part of the Snowy River EEC include the Lake Jindabyne, Lake Eucumbene, Lower Snowy River and the Murray River to Hume Reservoir Catchments.

Subject to the special arrangements applying to recreational fishing, the listing of the EEC in the catchment of the Snowy River in NSW has given all native fish and other aquatic invertebrates within its boundaries the status of endangered species (NSW DPI, 2012).

5.7 Fish and Crayfish Distribution Summary

A complete summary of threatened, non-threatened native and non native fish and invertebrates and their likelihood of occurrence across reservoirs and/or catchments throughout the study area is provided in **Annexure B**.

6 Assessment of Construction Impacts

6.1 Overview

Aspects of Snowy 2.0 construction with potential to affect aquatic ecology include:

- Construction of water intakes in Talbingo and Tantangara Reservoirs and their associated dredging and blasting works, including the construction of a barge ramp at Tantangara Reservoir;
- Edge push placement of excavated rock and dredge material in Talbingo Reservoir;
- Dry placement of excavated rock above MOL in Tantangara Reservoir;
- Surface infrastructure and utilities, including waterway crossings and fish barriers;
- Tunnel dewatering into Talbingo and Tantangara reservoirs;
- Tunnel excavation and groundwater drawdown; and
- Cumulative impacts.

6.2 Construction of Water Intakes and Associated Dredging and Blasting Works

6.2.1 Description of Impacting Processes

The intake structure at Talbingo Reservoir would be located at the south-east end of the reservoir, within the Yarrangobilly arm. The construction of the intake would be divided into two stages. First, the intake structure would be constructed with a rock plug in place to prevent reservoir water flowing into the tunnel and flooding the underground works. Second, the rock plug would be removed upon completion of all underground and tunnelling works.

Construction works would result in the disturbance of less than 0.75% of the total reservoir surface area. The maximum depth of water for the second stage of works (between FSL and intake channel invert level), is expected to be approximately 28 m. An approach channel would be positioned in front of the intake and excavated to have an overall vertical gradient in the order of 1:20. Areas of the approach overlaying unconsolidated soil/sediment would then be stabilised by rip rap if required. The total volume of excavated material (intake and approach channel) at Talbingo Reservoir would be approximately 100,000 m^3. The rock plug and approach channel would be excavated using a combination of drill and blast, and dredging, depending on the material type.

Where possible, the plug would be excavated using drill and blasting from the dry side in the excavated pit area. Where required, underwater blasting to break down the remaining rock material forming the plug would be carried out and material removed by a dredge or a barge-mounted excavator. Excavated material would be placed within the Ravine Bay placement location. A shoreline length of approximately 100 m would be lost due to the section that would be cut to accommodate the intake structure.

The intake structure at Tantangara Reservoir would be located at the south-west portion of the reservoir with construction divided into two stages as per the methodology outlined for Talbingo Reservoir. Less than 1% of the total reservoir bed would be disturbed during construction with excavated material being deposited in the designated placement location above FSL in the reservoir. The approach channel would be positioned in front of the intake to have an overall vertical gradient in the order of 1:10 and may be capped if required.

Snowy 2.0 would also require establishment of barge loading facilities on Tantangara Reservoir to enable removal of the rock plug for intake construction. The barge loading facilities for Talbingo Reservoir have been assessed as part of the Exploratory Works EIS (EMM, 2018). The estimated total volume of excavated material (intake, approach channel and barge ramp) at Tantangara Reservoir would be approximately 684,000 m^3.

Excavation and construction works are expected to take approximately 14 months at Talbingo Reservoir and approximately 13 months at Tantangara Reservoir.

There are several direct and indirect processes via which construction of the intake structures and dredging and blasting could potentially impact on aquatic habitats and associated biota within both reservoirs. These include:

- Direct - removal/modification of habitat and associated biota within the excavation footprints;
- Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;
- Direct – underwater noise and vibration from blasting;
- Indirect - changes to water quality; and
- Indirect – dredging related noise;

A Dredging Management Plan (DEEMP) to provide/confirm details including but not limited to the areas of dredging and disposal, the silt curtain design and permeability, gap between the bottom of the silt curtain and the lake floors, concentrations of suspended suspended sediment inside and outside the silt curtain, expected extent and intensities of noise and vibration, ecological monitoring, management of potential threatened species, etc.

Control measures would be initiated to minimise the extent of habitat loss or modification and, in particular, to contain the turbid plume generated by the mobilisation of fine sediments during dredging and blasting, and minimise mobilisation of sediment beyond the immediate work area. These measures and other details associated with dredging activiites would be included in the Dredging Management Plan (DEEMP). A loss of soft sediment, shoreline habitat and associated biota is expected and is discussed in detail below.

The direct and indirect impacting processes from dredging and blasting for construction of the intake structures would affect aquatic habitats and biota within both reservoirs and these are discussed below, with mitigation measures discussed in **Section 6.2.4**.

6.2.2 Talbingo Reservoir

6.2.2.1 Direct - removal/modification of habitat and associated biota within dredge and excavation footprint

As described in **Section 5.3.4**, habitats that would be affected by the excavation and dredging works for construction of the intake structures would include:

- Bare soft sediments (reservoir bed);
- Littoral rocky habitat (banks and shoreline);
- Submerged aquatic vegetation; and
- Large wooded debris (in the form of submerged dead trees remaining following the original filling of the reservoir).

Bare Soft Sediments

Soft sediment habitats occur within the dredge footprints of the proposed intake at Talbingo Reservoir. The benthic soft sediments in Talbingo Reservoir provide habitat for microbenthic infauna (invertebrates < 0.5 mm size) and meiofauna (invertebrates < 0.5 mm) living on or buried within the sediments of the reservoir beds, as well as freshwater macroalgae and periphyton (an assemblage of microalgae, cyanobacteria and heterotrophic microbes).

Sediment samples collected at the proposed intakes at Talbingo Reservoir contained typically large numbers of macroinvertebrates, including a large proportion of oligochaete worms, chironomids (the larvae of non-biting midges) and a small number of bivalve molluscs and nematode worms (**Section 5.3.3**). These groups are common to lacustrine systems and are abundant throughout Talbingo Reservoir, although the composition is patchy and variable at smaller spatial scales. The soft sediment habitat in and around the proposed intake is not unique but does have potential to experience localised impacts. For example, the loss of surface sediments containing benthic infauna, has potential to temporarily disrupt the capacity for nutrient cycling at a small scale. There would also be a localised loss of available food items for larger organisms with a potential cascading effect on the food web in that part of the reservoir. Larger mobile predators would, however, be able to seek similar prey elsewhere in the reservoir and would likely move away due to disturbances during construction.

Once excavation, dredging and construction of the intakes are complete, areas within the approach channel, not composed of rock, would be capped with rock rip rap. This would replacethe soft sediment habitat within the intake footprint and forming a new habitat likely to be colonised by a different assemblage of invertrbrates. Any remaining uncapped areas of soft sediment would likely become recolonised over time, although changes to flow patterns, water depth and sediment composition may initially result in a different infauna assemblage than previously occurred. Regardless, the loss of soft sediment habitat within Talbingo Reservoir would be negligible given the extensive area of similar habitat available throughout the reservoir. The removal of part of this habitat would be unlikely to have a long-term measurable effect on nutrient cycling or trophic interactions beyond the immediate vicinity of the excavated intake areas.

Rocky Habitat

Small, fringing areas of rocky habitat occur within the littoral zone of Talbingo Reservoir (including in proximity to the intake construction area). These areas extend a few metres below the surface of the steeply sloping littoral zone before being replaced by soft sediment habitats deeper into the reservoir. This is likely to provide habitat for fish and invertebrates living with the reservoir although they would not rely solely on this habitat for food and refuge.

Small aquatic macroinvertebrates can also be found on the underside of boulders and rocks and can form distinct communities compared with those found in other habitats such as soft sediments and macrophyte beds. Rocky habitat also provides a hard substratum for some aquatic vegetation to grow, such as algae, and therefore provides a grazing medium for small macroinvertebrates and some fish. Approximately 75 m of shoreline, including rocky habitat will be removed by excavation and construction of the intake structure. This represents a very small proportion of this habitat, which occurs throughout the reservoir including areas directly adjacent to the construction area.

Aquatic Vegetation

Submerged macrophytes including *Elodea* (non-native), *Potamogeton ochreatus* and *Nitella* sp. occur in the littoral zone (to approximately 2 - 10 m) throughout Talbingo Reservoir with very dense beds of *Elodea*, occurring throughout the Yarrangobilly River Arm and Middle Arm including at the proposed intake location. Macrophytes contribute to primary productivity and provide physical structure and habitat complexity for aquatic organisms, buffer nutrient levels, help trap sediment and oxygenate the water during photosynthesis (Thomaz & Cunha, 2010; Rejmankova, 2011). It is uncertain whether macrophytes would re-establish following completion of construction works. For example, currents occurring within the water column at the intake location during operation may prevent macrophytes from re-colonising in that area. As aquatic macrophytes can play a role as 'connecting' habitat for many species of fish, (Koehn & Nichol, 1998) there may be a temporary/permanent loss of connectivity among nearshore habitats on either side of the intake structure. These habitats also provide shelter from predators and a variety of food sources for optimum growth and survival of juvenile fish. Removal of aquatic vegetation fringing the shoreline at the intake structure footprints may therefore fragment fish habitat and reduce connectivity for some species during months when macrophytes usually occur.

Not all macrophyte removal, however, is considered a negative impact. *Elodea* is considered to be a nuisance species when it forms a dense monoculture (as is the case in much of Talbingo Reservoir) and its removal from the intake footprints is unlikely to unbalance nutrient levels or water chemistry at the scale of the reservoir. Zukowski & Whiterod, 2019 suggest that the dense stands of the introduced *Elodea* in the reservoir have been increasing over time and may have contributed to declines in Murray crayfish populations in Talbingo Reservoir. As a result, the potential loss of this habitat type from the construction area is more likely to have the effect of improving water quality and flow from the Yarrangobilly Arm into the reservoir which may otherwise be subject to choking, excessive shading and reduction in growth of other native species.

As a worst case scenario, the loss of such a small proportion of macrophyte habitat within Talbingo Reservoir is considered to be negligible given the extensive area of similar habitat throughout the reservoir. Extensive macrophyte beds elsewhere in the reservoir would provide alternative habitat for native fish and macroinvertebrates.

Submerged Timber

Submerged timber (or wooded debris) is extensive throughout Talbingo Reservoir as a result of damming and inundation of the forested river valley. It consists of whole trees, trunks and branches still rooted within the reservoir bed, as well as branches and tree stumps, but no leaves. Although artificially created, this habitat now provides bank stabilisation, habitat heterogeneity, shading / refuge for native fish and mobile macroinvertebrates and a substratum for attachment of periphyton, macroinvertebrates and macrophytes. It also provides a source of detrital input from its decomposition in the form of dissolved and solid organic carbon (NSW DPI, 2007).

Based on historical aerial imagery of Talbingo Reservoir (**Figure 6-1**), the density of wooded debris within the dredge footprint at the intake is relatively sparse compared with the rest of the reservoir and would be a very small proportion of the total similar habitat elsewhere in the reservoir. As such, this is not predicted to have a long-term impact on habitat availability at the scale of the reservoir and any fish or mobile macroinvertebrates would be able to move away to other extensive woody debris habitat adjacent to the construction footprint and elsewhere within the reservoir. No rehabilitation of habitat would occur within the intake area or channel to ensure that this area remain as unattractive as possble to fish and minimise the potential for entrainment into the completed intakes (**Section 7.2.2**).

Based on the receptors present, assessment of unmitigated risk levels for direct removal/modification of habitat and associated biota within the dredge and excavation footprint in Talbingo Reservoir ranged between low and moderate. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would be low (**Table 6-2**).

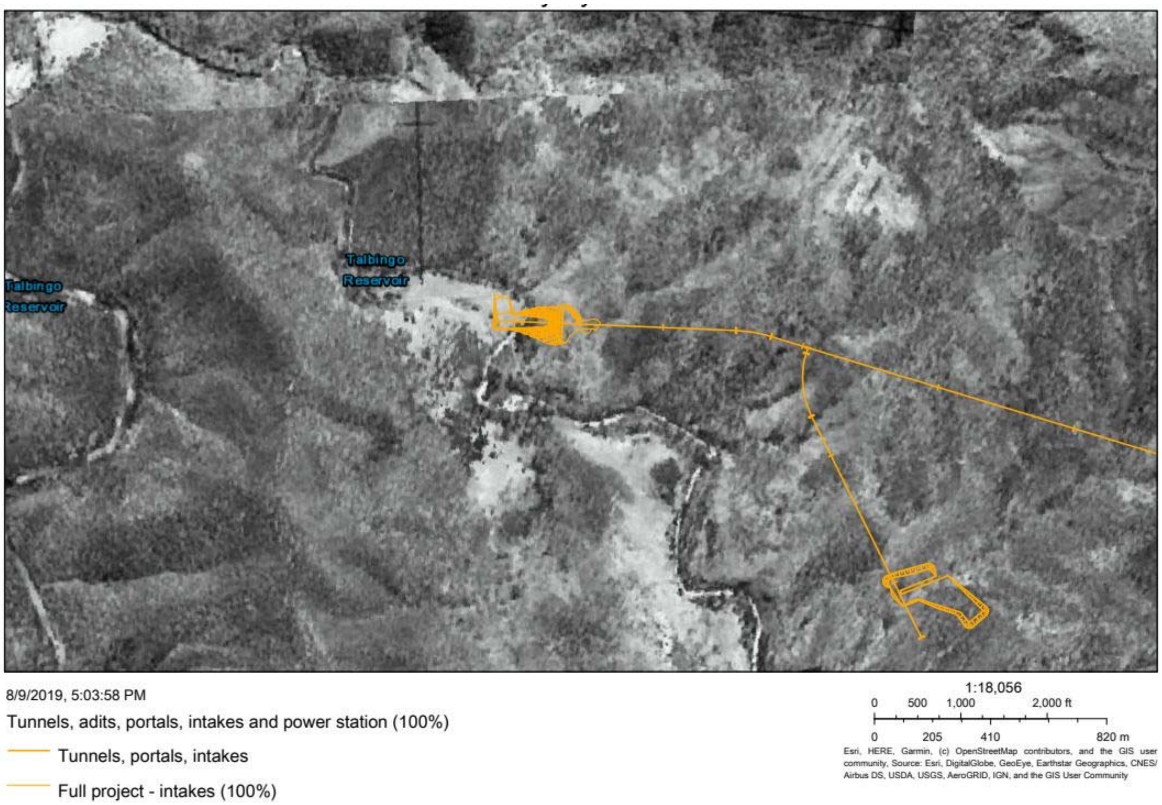

Figure 6-1 Historic aerial image of Middle Arm prior to dam construction indicating limited submerged timbers are likely at the intake area compared to other areas throughout Talbingo Reservoir.

6.2.2.2 Direct – hydraulic entrainment within dredge area

Depending on the final method of removal of soft sediment, there is potential for hydraulic entrainment, through the direct uptake of aquatic organisms by the suction field generated by methods such as draghead or cutterhead during dredging. Dredging methods causing entrainment can occur may result in the localised by-catch of fish eggs, larvae, mobile juveniles and adults (Wenger, et al., 2017). Mortality rates will vary among fish species and development stages (Griffith & Andrews, 1981) with eggs and larvae being most vulnerable (Wenger, et al., 2017). Documented entrainment rates of mobile fish species are generally low but are higher for demersal species (Drabble, 2012). Higher mortality is generally associated with cutter suction methods (Armstrong, et al., 1982). Other large mobile aquatic fauna such as crayfish are also at risk of direct mechanical or hydraulic entrainment although little is understood of their ability to avoid the dredge head. As an alternative to dredging methods that rely on suction, a long-reach excavator (mounted on a barge) may be used which would present minimal (if any) entrainment risk. Notwithstanding, as a conservative approach to the risk assessment, it has been assumed that some type of suction dredging would be required at some stage of intake construction.

Because of the short-term, small spatial scale and small volume of water (relative to the volume of the reservoirs) entrained during dredging, entrainment and subsequent mortality of fish, eggs and larvae would be relatively small. Furthermore, the vast majority of fish affected in Talbingo Reservoir would be non-native pest species (e.g. redfin perch and salmonids).

Murray crayfish may occur within the dredge footprint and intake construction area. Specific mitigation measures to manage this have been developed.

Based on the receptors present, assessment of unmitigated risk levels for hydraulic entrainment within dredge areas in Talbingo Reservoir ranged between low and moderate. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would be low (**Table 6-2**).

6.2.2.3 Direct – noise and vibration from blasting

In-water explosions produce a spherical shock wave that travels at speeds greater than the speed of sound in water and which produce a large oscillating gas bubble that radiates sound (Popper, et al., 2014). Blast signatures cover a range of frequencies from as low as 80 Hz, to in excess of 100 kHz (Spiga, et al., 2012). The mechanical disturbance is strong in the immediate vicinity and propagates away, reducing rapidly with distance. The high level pressure impulses produced from blasting are comparatively greater than those produced by seismic air guns and pile drivers. Measurements undertaken in marine borehole blasting using charge weights of 15 kg at a distance of 265 m (for example), recorded the pressure wave to vary from -3,000 Pa to 2000 Pa with the blast itself lasting for less than half a second. At this distance, the blast is characterised by a period of low frequency noise, followed by more broadband noise including much higher frequencies (Spiga, et al., 2012).

Biotic receptors living in the water column of Talbingo Reservoir that have potential to be directly affected by underwater noise and vibration associated with blasting include zooplankton (McCauley et al., 2017), macroinvertebrates (including crustaceans such as crayfish) (Spiga, et al., 2012), adult fish (native and non-native), larvae and eggs (Popper, et al., 2014). Most fish species found in Talbingo Reservoir are, however, introduced brown / rainbow trout or pest species (redfin perch) and impacts to these species are not considered as having a direct negative impact on aquatic ecology. Fish are particularly vulnerable to underwater noise if they have a gas bladder in the body and depending on the anatomical location of the gas bladder, different species may be more or less susceptible to pressure-mediated injury to the ears and general body tissues (Carlson, 2012). All of the fish species known or potentially occurring within Talbingo Reservoir are bony (teleost) fish and have swim bladders. As crayfish do not have swim bladders, the range at which an explosive event could cause physiological damage is likely to be several orders of magnitude less than for a fish with a swim bladder (Popper, et al., 2014).

The direct effects of underwater noise on aquatic biota include heightened physiological stress (leading potentially to mortality), masking of biologically important sound (e.g. for communication, predator/prey detection), auditory injury (also referred to as permanent or temporary threshold shift), and in extreme cases, direct or indirect mortality (Popper, et al., 2014; Southall, et al., 2007).

In determining the sensitivity and impact of underwater noise on different species or receptors, there are two main components to consider. These are ‘sound pressure’ (Db) and ‘particle motion’. Particle motion (displacement, velocity, and acceleration) stimulates the otolithic organs within the ears of fishes (which sense movement and balance). While some fish species are able to detect sound pressure indirectly, fish and aquatic invertebrates primarily sense particle motion (Nedelec, et al., 2016). At present, there are no noise exposure criteria for particle motion, and existing criteria (even for species which sense only particle motion), are based solely on sound pressure (Popper, et al., 2014). Applying noise exposure criteria for impact assessment is also difficult due to inconsistencies between the acoustic metric modelled used to predict risk and the acoustic metric defining the exposure threshold. For example, the criteria used to measure impulsive sound, such as blasts are generally defined using either zero-to-peak sound pressure level (SPL), peak-to-peak SPL or cumulative sound exposure level (SEL), however, there are no direct conversions among these metrics (Faulkner, et al., 2018). Predictions of noise levels should therefore aim to compare the same units of measurements, but will not always be possible. The relative sensitivities of these groups based on existing information is discussed below.

Fish

Sound exposure guidelines have been developed for fishes that are based upon a single explosion from relatively small charges used to dismantle in-water structures (Hubbs & Rechnitzer, 1952) in (Popper, et al., 2014). For adult fish (with or without swim bladders), these provide a peak pressure level value of between 229 – 234 dB as enough to cause direct mortality and potential mortal injury. The risk of a recoverable injury is also considered to be relatively high at intermediate distances from the sound source and low at relatively far distances from the sound source. Different expectations would be likely for larger or multiple explosions and for eggs and larvae.

The limitation of setting guidelines is that the studies examining the effects of explosions on fishes have used different species, different types of explosives, and/or charges of different weights. As such, these guidelines represent the lowest amplitude that caused consistent mortality. Wright & Hopky, 1998 report that sub-lethal effects in fish, including changes in behaviour, have also been observed as a result of noise produced by explosives. The effects may be intensified in the presence of hard substrata and the degree of effect is related to the type of explosive, size, and pattern of the explosive charge(s), method of detonation, distance from the point of detonation, water depth, and species, size, and life stage of fish.

Macroinvertebrates

Some invertebrates, including crustaceans, may be sensitive to substratum vibrations and it has been seen that a number of aquatic decapod crustaceans (such as crayfish) produce sounds, and are able to detect substratum vibration at sensitivities sufficient to detect the proximity of mates, competitors, or predators (Popper, et al., 2014). Whether these invertebrates respond to propagated sound waves at a distance from the source remains uncertain. Spiga, et al. (2012) conclude that although some adult crustaceans are affected by exposure to high-level seismic sources, the effect is often minimal. In some cases, no detectable response has been observed and there is no evidence of impact of seismic surveys upon catches in crustacean fisheries. This may not be the case for impulsive explosions which would generate relatively higher peak pressure levels in an enclosed freshwater environment such as a reservoir.

Zooplankton

Low frequency noise from seismic airguns can cause significant mortality in zooplankton populations in the marine environment (McCauley, et al., 2017). In this study, a two to threefold increase in dead and adult zooplankton, with total mortality of all larval krill occurred within a 1.2 km range of the source. While no direct comparisons can be made with these results to proposed blasting at Talbingo Reservoir, it is reasonable to assume some level of zooplankton mortality within the immediate blast area given it would occur in enclosed waters and that noise propagating from a blast is expected to have a greater sound pressure than a seismic air gun. Indirect effects could also include short-term changes in trophic interactions via the loss of zooplankton as a food source for planktivorous fish and invertebrates and/or via an increase in phytoplankton and detritus in the reservoir ecosystem in the absence of zooplankton regulation. Provided that blasting activities are short-term and localised zooplankton assemblages would recover post-construction. The rate of recovery would depend on the extent of the initial impact and whether other ecosystem components such as water and sediment quality are restored. Depending on the overall level of mortality, recovery would take months up to several years (Larson, et al., 2006), in the absence of other potential impacts (e.g. water transfer) but is likely to return to pre-blasting conditions.

The extent of impacts of blasting on aquatic receptors will depend on several factors including:

- The likely maximum sound pressure levels that will be generated;
- How sound pressure levels will propagate throughout the reservoir;
- Frequency and duration of the blasts; and
- Sensitivities of different receptors to the sound levels expected over the course of construction works.

Designated blast limits and other management measures to minimise impacts to aquatic ecology would be contained in Blast Management Plan along with other mitigation measures listed in **Section 6.2.4**.

Further information around the impacts and residual risks of suspended sediments (including contaminants) and sedimentation is in **Section 6.2.2.4**.

Based on the receptors present, assessment of unmitigated risk levels of noise and vibration from blasting in Talbingo Reservoir would be moderate. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would be low to moderate (**Table 6-2**).

6.2.2.4 Indirect - changes to water quality

Suspended sediment and turbidity

As would be described in the proposed DEMMP, a silt curtain would be deployed around the dredging areas to contain the spread of suspended fine sediments mobilised during dredging, excavation works and emplacement where practicable. As described in **Section 5.3.3** current estimated average rate of sedimentation near Middle Bay is around 15 mm per year and is greater further upstream. Data collected between 1989 and 2003, indicates water clarity within Talbingo Reservoir is generally good (turbidity ~ 2 NTU) and well within ANZECC / ARMCANZ (2000) guidelines (Cardno, 2019). The concentration of suspended sediment and turbidity within the silt curtain during blasting and dredging activities is expected to be relatively high and remain suspended in the water column for extended periods. Receptors likely to occur within the water column (and potentially be trapped within the proposed silt curtains) at both reservoirs include plankton, fish larvae, adult fish and crayfish. Based on fish populations known to occur within Talbingo Reservoir, this would mostly include stocked salmonids and redfin perch. Murray crayfish and common yabbies are also likely to occur.

Individuals contained within the silt curtains during works would be temporarily subject to impacts due to high concentrations of suspended sediment, but some may be able to escape under the silt curtain through the gap between the curtain and the reservoir floor. The extent of the effect of elevated suspended sediment and associated turbidity on biota would depend on the duration of exposure, concentration and sensitivity and / or life stage of the individuals affected. Studies investigating the effects of suspended sediments on different types of freshwater, anadromous, estuarine and marine fish indicate that suspended sediments can result in behavioural changes, physical damage, physiological stress, sub-lethal responses and in some cases mortality (Wenger, et al., 2017). Behavioural changes are likely to involve avoidance of turbid water (Collin & Hart, 2015), which has been demonstrated in rainbow trout, and impairment of visual perception which can in-turn negatively affect predation and foraging success (Utne-Palm, 2002). It has been found that foraging in planktivorous and piscivorous fish can be impaired by suspended sediment and that sedimentation affects herbivory (Utne-Palm, 2002). Prolonged exposure to suspended sediments can also lead to physiological effects which can damage and clog gills, therefore impairing respiratory efficiency. Due to their higher oxygen demand, larval stages may be more vulnerable to reduced efficiency in oxygen uptake compared to more developed life stages. Collin & Hart (2015) note that increased suspended sediment and turbidity can also reduce the amount of dissolved oxygen in water, thus having a cumulative impact on these sub-lethal effects.

Murray crayfish have been detected in low abundance within the construction footprint (Zukowski & Whiterod, 2019). As such, pre-clearance surveys would be undertaken to minimise the risk of Murray crayfish, occurring within the intake construction area prior to disturbance. If any fish are trapped behind the silt curtain during works, the majority of these are likely to be non-native, stocked trout or pest species, although there is a chance that some could be native fish. There is also potential for Murray crayfish not collected during pre-clearance and relocation activities to be present in the dredge area. These individuals may be subjected to sub-lethal effects and potential mortality as a result of high concentrations of suspended sediments and turbidity.

Notwithstanding this, given the affected areas are very small (i.e. less than one per cent) relative to the extent of these habitats in the reservoirs, this type of impact would not be of concern to the broader ecological functioning of fish or invertebrate communities, or the viability of a local population of fish or the Murray crayfish. It is likely that assemblages within the affected areas would recover rapidly once all construction works have ceased, subject to consideration of operational impacts.

Contaminants

Surface sediments (20 – 30 cm) within the dredge footprint of the intakes at Talbingo Reservoir consist of soft, muddy, fine textured, predominantly coarse silts (**Section 5.3.3**). Results of testing indicated that these sediments, if mobilised would be unlikely to present any risk to the aquatic environment via the release of contaminants such as lead, nickel and zinc (RHDHV, 2018). Trace metals mobilised during dredging are likely to remain bound to sediment particles and are unlikely to dissociate and be released into the water column as dissolved phases. The minor component of contaminants that might be released to form dissolved phases would likely be re-adsorb to suspended particulates and eventually resettle to the reservoir bed. Thus, the pathway for spread of contaminants would be restricted to the component of dredged sediment in the water column that settles back onto the reservoir bed within the silt curtain or escapes from the silt curtains and settles back onto the reservoir bed outside the silt curtain.

Impacts of mobilised contaminants on biota would vary with species, concentration, contaminant and environmental conditions. Tolerances to contaminants may also vary at a population level for a species due to phenotypic or genotypic variation. Fish can suffer from direct exposure to suspended contaminated sediments which can impair chemosensory functions, impair feeding and reduce their response to external stimuli (Roberts, 2012). The impacts of metal contaminated suspended sediment on fish have potential to cause direct effects on reproductive output and early development via a range of mechanisms (Jezierska, et al., 2009). In adult fish, for example, zinc has been linked to a reduction in sperm motility and elevated levels of lead linked to oxidative stress and disruption of thyroid hormones (Abascal, et al., 2007; Jezierska, et al., 2009). Filter feeding organisms are particularly susceptible to suspended contaminants, given their ability to accumulate from both dissolved contaminant and particulate bound exposure pathways (Cruz-Rodriguez & Chu, 2002). This could include freshwater macroinvertebrates such as bivalves and some species of insect larvae and crustaceans. Studies have shown that bivalves and polychaete worms can exhibit reduced feeding activity and suffer from a range of histopathological effects which can ultimately affect reproduction and respiration (Roberts, 2012). In addition, many of the contaminants recorded in the sediment quality assessment for the study area can potentially bioaccumulate, which can lead to a greater risk of chronic poisoning within these aquatic organisms.

Although there may be impacts to some biota, the affected areas are expected to be very small (i.e. < 1 % relative to the extent of these habitats in the reservoirs). Hence, this type of impact would not be of concern to the broader ecological functioning of fish or mobile invertebrate communities within the reservoir. It is expected that fish or mobile invertebrate communities within the affected areas would recover once the source of contamination is no longer suspended in the water column.

It is unlikely that soft sediment areas would be exposed to new or increased contaminants from dredging or blasting. Given there are already elevated levels of some metals within soft sediment habitats within the construction footprints, there would be no additional effects on benthic infauna from resettled contaminants. These activities are unlikely to change the ambient quality of sediment in existing areas as contaminant concentrations in sediment within the dredge footprints are similar to those adjacent to the footprints.

The DEMMP and BMP would include measures to avoid risks of contaminant exposure during dredging and excavation.

Based on the receptors present, assessment of unmitigated risk levels for changes to water quality in Talbingo Reservoir ranged from low to moderate. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would be low (**Table 6-2**).

6.2.2.5 Indirect Impacts – dredging noise

Guidelines for exposure to underwater noise (including both marine and freshwater receptors), exist for fishes, eggs and larvae (Popper, et al., 2014), however, these do not specifically include dredging as a sound source (Wenger, et al., 2017). Some studies, however, have quantified underwater dredging noise from hydraulic and mechanical dredging (Reine, et al., 2014) and suggest that dredging generally does not produce intense sounds comparable to pile driving and other in-water construction activities, but rather lower levels of continuous sound at frequencies generally below 1 kHz (Wenger, et al., 2017), although this is greater where breaking of rocks is required. As dredging will take place within enclosed waters, the intensity and effects of underwater noise are likely to be intensified as sound reflects off hard surfaces.

That considered, the duration of the dredging works would be temporary and short term during intake construction. At most, the effects of dredging related sound on adult fish are likely to include behavioural effects (i.e. flight from the noise source) and at worst, temporary hearing loss, rather than physiological damage. Overall, the impact of dredging related noise is expected to be much less intense than that for blasting and would have a low level of risk to the sensitive receptors identified (including Murray crayfish and trout cod).

Based on the receptors present, assessment of unmitigated risk from dredging related noise in Talbingo Reservoir would be low. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would remain as low (**Table 6-2**).

6.2.2.6 Impacts on KFH, Threatened Species and EECs

The relatively small areas of submerged macrophytes and wooded debris occurring within the construction footprint at the intake structure would be permanently lost as a result of the dredging and blasting works. Similar areas of submerged aquatic vegetation and wooded debris are present throughout Talbingo Reservoir. As such, destruction of areas within the intake construction footprint would be unlikely to significantly affect fish or invertebrates as they would seek similar habitat elsewhere. Consideration will be given to using wooded debris that may be cleared from the intake area to rehabilitate disturbed areas away from the intake locations following construction works. The procedure for potential removal would be outlined within the AqHMP. Notwithstanding the above discussion, dredging and blasting would cause a very small but permanent change to a type 1-KFH.

Threatened and protected species that are known or likely to occur within the proposed intake areas at Talbingo Reservoir include:

- Trout cod (*Maccullochella macquariensis*): Occurs (stocked population); and
- Murray crayfish (*Euastacus armatus*): Occurs and Caught;

A self-sustaining and broadly distributed population of Murray crayfish, occurs within Talbingo Reservoir (Zukowski & Whiterod, 2019) including areas in and around the proposed intake structures. Latest surveys (carried out in June 2019) found three individual Murray crayfish at depths between 3.2 m and 7 m in and around the vicinity of proposed intake structures (Zukowski & Whiterod, 2019). Excavation would take place from the shoreline to a depth of approximately 28 m below FSL, which includes habitat in the depth range where Murray crayfish are known to occur and build burrows (i.e. between 2 and 17 m). As Murray crayfish have relatively small home ranges and low dispersal abilities (NSW DPI, 2019c), they would be vulnerable to both direct impacts of habitat removal and entrainment and indirect impacts to water quality and acoustic disturbance. In particular, Murray crayfish are considered to be intolerant to low levels of dissolved oxygen and in extreme cases, this has led to local population depletion (NSW DPI, 2019c). Murray crayfish populations within the reservoir also appear to be in decline, potentially due to the increases of introduced *Elodea* (Zukowski & Whiterod, 2019).

Prior to any dredging or excavation activities, targeted sampling would be carried out in and around the proposed dredging and excavation areas to collect Murray crayfish that may occur there. The timing and methodology of sampling would be outlined in the AqHMP and developed in consultation with NSW DPI. Murray crayfish not captured during pre-clearance surveys could be vulnerable to short-term, localised impacts with a risk of mortality or sub-lethal effects due to dredging and blasting, elevated turbidity, habitat loss/fragmentation or excess sedimentation. Depending on the extent of noise propagation, Murray crayfish could also be subject to more far reaching effects from underwater blasting noise, such as behavioural changes, sub-lethal physiological stress and /or mortality.

Murray crayfish occur in many locations in Talbingo Reservoir (Zukowski & Whiterod, 2019) and those occurring within the intake construction and dredge area that are not relocated would be a small proportion of the total population. It is therefore unlikely that the proposed intake construction and dredging works would affect the viability of the Talbingo Reservoir population to the extent that the population could not naturally recover following completion of construction.

A stocked population of trout cod occurs within Talbingo Reservoir but they were not detected in any surveys. Their occurrence and subsequent containment in the silt curtain at the time of intake construction would be unlikely and have only minor consequences to the population as a whole. Furthermore, any fish or mobile macroinvertebrates contained within the silt curtain could potentially escape beneath the bottom of the curtain (as these would be open at the reservoir bed).

6.2.2.7 Key Threatening Processes

Construction of the intake, dredging and blasting in Talbingo Reservoir would have potential to facilitate the following KTPs:

- Degradation or native riparian vegetation along New South Wales water courses (FM Act); and
- Removal of large woody debris from New South Wales rivers and streams (FM Act).

The area of vegetation adjacent to the reservoir that is likely to be impacted by intake construction will be very small relative to the total area of shoreline vegetation around Talbingo Reservoir. Similarly, the area of wooded debris occurring within the construction footprint at the intake structure is small relative to the total area in the reservoir. In addition as shown in **Figure 6-1** above, limited submerged timbers are likely at the intake area compared to other areas throughout Talbingo Reservoir.

6.2.3 Tantangara Reservoir

6.2.3.1 Direct - removal/modification of habitat and associated biota within dredge and excavation footprint

Habitats that would be excavated and dredged to construct intakes and the barge ramp would include the benthic and littoral zone of Tantangara Reservoir. The main differences between Tantangara and Talbingo reservoirs are the absence in the former of submerged trees, lack of macrophytes and different composition of littoral vegetation which consists mainly of bare ground with some low profile heath and grasses. The benthic soft sediments in Tantangara Reservoir are similar to Talbingo Reservoir, numerically dominated by a large proportion of oligochaete worms, chironomids (non-biting midges) and nematode worms (**Section 5.4.6**). Macrophytes were not generally identified at sites investigated during surveys undertaken at Tantangara Reservoir, including the proposed intake structure, apart from one small isolated patches of *Elodea* (**Section 5.4.4**).

The loss of less than 1 % of benthic soft sediment habitat within Tantangara Reservoir is assessed to be negligible given the extensive area of similar habitat and infauna elsewhere in the reservoir.

Based on the receptors present, assessment of unmitigated risk levels for direct removal/modification of habitat and associated biota within the dredge and excavation footprint in Tantangara Reservoir was low. The residual risk following the implementation of the mitigation measures identified in **Section 6.2.4**, remains as low (**Table 6-2**).

6.2.3.2 Direct – hydraulic entrainment within dredge area

Risks of hydraulic entrainment of biota during dredging operations at Tantangara Reservoir would be similar to that described for Talbingo Reservoir. Native species occurring in Tantangara Reservoir that could be susceptible to entrainment include the common yabby and Reik's crayfish. No threatened species have been identified as occurring within Tantangara Reservoir (**Section 5.4.5**). Based on the receptors present, assessment of unmitigated risk levels for hydraulic entrainment within dredge areas in Tantangara Reservoir were low and there are no mitigation measures that would further reduce this risk (**Table 6-2**).

6.2.3.3 Direct – noise and vibration from blasting

Biotic receptors living in the water column of Tantangara Reservoir that have potential to be directly affected by underwater noise and vibration associated with blasting include zooplankton (McCauley, et al., 2017), macroinvertebrates (including crustaceans such as crayfish) (Spiga, et al., 2012), adult fish, larvae and eggs (Popper, et al., 2014). The vulnerability of aquatic organisms to underwater noise and vibration are broadly discussed in **Section 6.2.2.3**. No threatened species would be at risk (**Section 5.4.5**). Designated blast limits and other management measures to minimise impacts to aquatic ecology would be provided in the Blasting Management Plan. Based on the receptors present, assessment of unmitigated risk levels for noise and vibration from blasting in Tantangara Reservoir was moderate. The residual risk following the implementation of the mitigation measures identified in **Section 6.2.4**, remained as moderate as some native species are still likely to be affected within the zone of influence. This would not result in permanent change to the existing population and recovery to pre-existing conditions would be expected on completion of construction (**Table 6-2**), subject to consideration of operational impacts.

6.2.3.4 Indirect - changes to water quality

As indicated in **Section 5.4.3** sediments throughout Tantangara Reservoir are classified as soft and muddy with small clay fractions and do not show elevated levels of metal contaminants. Impact pathways from increased suspended sediments and turbidity on biota within Tantangara Reservoir would be similar to those described for Talbingo Reservoir, although adverse impacts from the mobilisation of contaminants would not be expected given the sediment testing results. Species known to occur in Tantangara Reservoir potentially affected could include introduced brown and rainbow trout, native common yabbies and Reik's crayfish. Threatened aquatic species are not known to occur in the reservoir. On this basis, indirect risks of changes to water quality would be comparatively less for Tantangara Reservoir than for Talbingo Reservoir. Based on the receptors present, assessment of unmitigated risk levels for indirect changes to water quality in Tantangara Reservoir range from low to moderate. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would be low (**Table 6-2**).

6.2.3.5 Indirect – dredging related noise

Noise related impacts associated with intake construction and dredging at Tantangara Reservoir would be similar to that described for Talbingo Reservoir, although the timing and duration of works would vary and the receptors would differ. Overall impacts on sensitive receptors within Tantangara Reservoir (such as native fish and crayfish), would be minor and limited to avoidance behaviour over a relatively short time frame. Therefore, based on the receptors present, assessment of unmitigated risk from dredging related noise in Tantangara Reservoir is low. The residual risk, following the implementation of the mitigation measures identified in **Section 6.2.4** would remain as low (**Table 6-2**).

6.2.3.6 Impacts on KFH, Threatened Species and EECs

6.2.3.7 Intake construction and dredging within Tantangara Reservoir would affect a very small areaof type 2 KFH. This would be within the relatively small footprint compared withf the overall area of the reservoir.Given the absence of submerged trees and macrophytes, the value of the fish habitat lost would be minimal and available elsewhere within the reservoir. No EECs occur within Tantangara Reservoir.Key Threatening Processes

Construction of intakes and dredging would have potential to facilitate the following KTPs within Tantangara Reservoir:

> Degradation of native riparian vegetation along New South Wales water courses (FM Act);

Very little riparian vegetation is present along the shoreline of Tantangara Reservoir and of this, only a minimal amount is expected to be impacted. No wooded debris was observed within the construction footprint.

6.2.4 Mitigation Measures and Residual Risks

Mitigation measures outlined in **Table 6-1** would be implemented to control risks relating to intake construction, dredging and blasting in both reservoirs.

Table 6-1 Mitigation measures to control risks relating to intake construction, dredging and blasting.

Mitigation Code	Description
AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills and implement clean-up measures as appropriate; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
AE07	All dredging works would be closely monitored and carried out in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP)
AE08	A silt curtain will be deployed in each reservoir to minimise the spread of turbid water/suspended solids beyond the footprint, where practicable

AE09	Contaminated sediments and soils posing a risk to aquatic habitats would be managed in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP)
AE06	Designated blast limits would be determined and implemented, and other management measures implemented to minimise impacts to aquatic ecology – these actions would be described in the Blast Management Plan

Provided that the mitigation measures outlined above are implemented then the residual risks of intake construction and dredging on aquatic receptors within each of the reservoirs / catchments would be low to moderate (**Table 6-2**).

Table 6-2 Qualitative risk assessment of likelihood and consequences of intake construction and dredging before and after proposed mitigation. L=Likelihood of occurrence; C = Consequence of occurrence. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Minor	Mod	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Minor	Low
		Native aquatic species	Almost certain	Insig	Low	Almost certain	Insig	Low
		Salmonids	Possible	Minor	N/A	Possible	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Almost certain	Insig	Low	Almost certain	Insig	Low
		Salmonids	Possible	Minor	N/A	Possible	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Possible	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Minor	Low
		Native aquatic species	Possible	Insig	Low	Possible	Insig	Low
		Salmonids	Possible	Insig	N/A	Possible	Insig	N/A
		Planktonic assemblages	Almost certain	Insig	Low	Almost certain	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Possible	Insig	Low
		Salmonids	Possible	Insig	N/A	Possible	Insig	N/A
		Planktonic assemblages	Almost certain	Insig	Low	Almost certain	Insig	Low
Direct – noise and vibration from blasting	Talbingo Reservoir	Threatened aquatic species - Trout cod	Likely	Minor	Mod	Possible	Minor	Mod
		Threatened aquatic species - Murray crayfish	Likely	Minor	Mod	Unlikely	Insig	Low
		Native aquatic species	Likely	Minor	Mod	Likely	Minor	Mod
		Salmonids	Likely	Minor	N/A	Likely	Minor	N/A
		Planktonic assemblages	Likely	Minor	Mod	Likely	Insig	Low

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Likely	Minor	Mod	Likely	Minor	Mod
		Salmonids	Likely	Minor	N/A	Likely	Minor	N/A
		Planktonic assemblages	Likely	Minor	Mod	Likely	Minor	Mod
Indirect - changes to water quality (via sediment mobilisation during dredging)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Likely	Minor	Mod	Possible	Insig	Low
		Threatened aquatic species - Murray crayfish	Likely	Minor	Mod	Possible	Insig	Low
		Native aquatic species	Likely	Minor	Mod	Likely	Insig	Low
		Salmonids	Likely	Insig	N/A	Possible	Insig	N/A
		Planktonic assemblages	Likely	Insig	Low	Likely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Likely	Minor	Mod	Likely	Insig	Low
		Salmonids	Likely	Insig	N/A	Likely	Insig	N/A
		Planktonic assemblages	Likely	Insig	Low	Likely	Insig	Low
Indirect - Dredging related noise	Talbingo Reservoir	Threatened aquatic species - Trout cod	Likely	Insig	Low	Likely	Insig	Low
		Threatened aquatic species - Murray crayfish	Likely	Insig	Low	Likely	Insig	Low
		Native aquatic species	Likely	Insig	Low	Likely	Insig	Low
		Salmonids	Likely	Insig	N/A	Likely	Insig	N/A
		Planktonic assemblages	Likely	Insig	Low	Likely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Likely	Insig	Low	Likely	Insig	Low
		Salmonids	Likely	Insig	N/A	Likely	Insig	N/A
		Planktonic assemblages	Likely	Insig	Low	Likely	Insig	Low

6.3 Edge Push Placement of Excavated Material

6.3.1 Description of Impacting Processes

It is expected that approximately 2,830,000 m^3 of excavated material will be placed into each of the reservoirs. Prior to placement, excavated rock would be systematically tested and its suitability determination for:

> Re-use as a construction material for the project as aggregate, manufactured sand or pad construction; or

> Placement within Tantangara and Talbingo reservoirs.

Placement of suitable rock material within Talbingo Reservoir would consist of material being progressively pushed from shore into the reservoir with the use of conventional earth-moving plant. When there is sufficient material available, the material would be placed in stages at the disposal site to better manage the release of fines, with drill and blast material placed on the outer edge, and in-filling with TBM material A silt curtain would be established around the footprint of the proposed excavated rock emplacement site to minimise the release of fine material into Talbingo Reservoir.

Placement of excavated material in Tantangara Reservoir would involve staged placement predominantly within the active storage area of Tantangara Reservoir by conventional earth-moving plant, such as dump trucks and excavators working above the active water level. The final landform will be raised to approximately 1 m above full supply level (FSL) to allow for the introduction of recreational facilities and rehabilitated areas that are to be agreed upon in further consultation with NPWS and other key stakeholders.

Placement of excavated material in Tantangara would be carried out in stages from the boundary of FSL towards the minimum operating level (MOL) area of the reservoir. To minimise the disturbed areas and unprotected excavated rock emplacement slope surface, staged containment excavated rock cells are proposed.

Water quality monitoring associated with this activity will be detailed in the WMP.

The direct and indirect impacts associated with excavated material placement include:

- Direct Impacts:
  - Loss/modification of aquatic habitat due to smothering;
  - Displacement/direct mortality of existing aquatic organisms; and
  - Changes to sediment quality within the proposed placement areas.
- Indirect Impacts
  - Changes to water quality.

6.3.2 Talbingo Reservoir

6.3.2.1 Impacts on Aquatic Habitats and Biota

The aquatic habitats located within the proposed excavated material placement area footprint in Talbingo Reservoir include:

- Bare soft sediment;
- Rocky habitat;
- Aquatic vegetation (macrophytes and macroalgae); and
- Submerged timber.

Each of these habitats provide an environment for various aquatic biota and each plays a different role in the structuring of aquatic assemblages and the ecological processes that are part of these environments.

6.3.2.2 Direct - Loss/modification of aquatic habitat due to smothering

Bare Soft Sediments

Bare soft sediment habitat makes up the largest area of benthic aquatic habitat within the proposed placement area of Talbingo Reservoir. As highlighted in **Section 5.3.6**, the soft sediment environment provides habitat to a range of organisms including benthic infauna (micro-, meio- and macro-), freshwater algae and macrophytes, and fish. Benthic infauna are generally the most numerically dominant organisms associated with this habitat (as discussed in **Section 5.3.6**).

Excavated rock placement in Talbingo Reservoir would be undertaken from the shore with the use of excavators to progressively push excavated material into the reservoir. The size of the excavated rock material is expected to range from boulder (>200 mm) to clay (<0.002 mm). Therefore, the replacement of soft sediment habitat within this region with excavated rock would most likely change the physical characteristics of this environment. The area within the placement footprint would most likely be made up of material with larger particle sizes (i.e. greater than coarse sand, >2mm) which would settle onto the substratum more rapidly. Sediment particle size would then decrease with increasing distance from the placement footprint, as finer particles would remain in the water column for longer periods of time allowing for a greater dispersal area.

The placement footprint area between MOL and FSL represents less that 1.5 % of the reservoir area. Given the affected area amounts to only a small proportion of the extent of this habitat in the reservoir, any removal/modification of soft sediment habitat from placement activities is not expected to adversely impact the amount of this habitat at the scale of the reservoir. In addition, the placement of larger sized particles such as boulders and cobble into this area (which is mostly void of this type of habitat) would contribute to some degree to habitat complexity and heterogeneity within the area.

Rocky Habitat

Small, fringing areas of rocky habitat occur within the littoral zone of Talbingo Reservoir (including within the vicinity of the proposed excavated material placement areas). Due to the steep nature of the littoral zone within the reservoir however, these rocky areas generally extend only several metres below the surface and are often rapidly replaced by soft sediment habitat further into the reservoir.

The proposed placement of excavated rock within Talbingo Reservoir would smother some small, isolated areas of this habitat and would thus result in the mortality of any benthic invertebrates associated within this habitat. Given the extent of this habitat in the reservoir is small and represents a very minor component of the aquatic habitat present within the proposed placement area, the loss of the existing rocky habitat as a result of excavated material placement would not be ecologically significant. In addition, the placement of excavated rock, over time, potentially compensate for any loss of, and increase the amount of existing rocky habitat in these areas, which would have the potential to add to habitat heterogeneity and potentially have a positive benefit to any organisms that utilise this habitat.

Aquatic Vegetation

Aquatic vegetation occurs throughout much of the fringing margins and shallower regions of the proposed excavated material placement area within Talbingo Reservoir down to approximately 10 m. In some places, large areas of submerged macrophytes and algae occur along the northern shoreline within the vicinity of Ravine Bay and into Middle Creek in close proximity to the placement footprint. As previously noted exotic *Elodea* is the most dominant species in this area. The placement of excavated material would disturb and smother any aquatic vegetation present within the placement area.

The loss of aquatic vegetation within the reservoir resulting from excavated material placement is considered negligible given the extensive area of similar habitat throughout the reservoir. Further, it is expected that macrophytes would re-establish in the placement areas within a few years. In the intervening period, extensive macrophyte beds adjacent to and elsewhere in the reservoir would have the potential to provide alternative habitat for biota present within the reservoir.

Submerged Timber

Submerged timber is extensive throughout Talbingo Reservoir, including within the proposed excavated material placement area. As suggested in **Section 6.2.2.1**, this submerged timber provides bank stabilisation, habitat heterogeneity, shading/refuge for native fish and mobile macroinvertebrates, provides a substratum for periphyton, macroinvertebrates and aquatic plants to attach and is a source of detrital input from its decomposition in the form of dissolved and solid organic carbon.

Submerged timber is widespread throughout Talbingo Reservoir. The removal/loss of submerged timber within the proposed excavated material placement area would represent a very small proportion of the submerged timber habitat within Talbingo Reservoir. Although other suitable areas of this habitat occur within the reservoir, the loss of submerged timber within Ravine Bay has the potential to cause localised effects on aquatic faunal assemblages (fish and aquatic macroinvertebrates). On a reservoir scale, the loss of submerged timber within the proposed excavated material placement area is unlikely to cause any long-term impacts on habitat availability.

Based on the receptors present, assessment of unmitigated risk levels for “Loss/modification of aquatic habitat due to smothering” within Talbingo Reservoir range between Low and Moderate (**Table 6-5**). The residual risk to sensitive receptors, following the implementation of the mitigation measures identified in **Section 6.3.4**, would be Low (**Table 6-5**).

6.3.2.3 Direct - Displacement/direct mortality of existing aquatic organisms

Soft Sediment Biota

Sediment samples collected near the proposed placement areas (i.e. Ravine Bay/Middle Creek) contained large numbers of benthic invertebrates, in particular oligochaete worms. This was also the case for other locations sampled within the reservoir, indicating that the soft sediment habitat in and around the proposed excavated material placement areas is not considered to be unique with respect to benthic infauna. The proposed excavated rock placement within Talbingo Reservoir would disturb this habitat, via smothering, and have the potential to displace or cause mortality to benthic infaunal assemblages residing within sediments within the placement areas. Mortality to benthic epifauna and infauna in soft sediments could potentially cause flow on effects with respect to nutrient cycling within sediments and impacts on food webs and various trophic interactions within the reservoir.

Given the excavated material placement area amounts to a small proportion of Talbingo Reservoir and recovery is expected to occur following the cessation placement activities, the loss of soft sediment biota would be temporary and amount to only a minor localised impact with no flow on impacts to the rest of the reservoir.

Rocky Habitat Biota

Following placement of excavated material, there is the potential for the material to become colonised with microalgae and its own macroinvertebrate assemblages, although significant changes to depth and sediment composition may initially result in a different assemblage than had previously occurred. It is also possible that the addition of the excavated material could provide additional habitat complexity and heterogeneity to what already exists within these areas, which has the potential to benefit biodiversity in the aquatic biota that utilise these areas.

Aquatic Vegetation

Impacts on biota associated with aquatic vegetation within Talbingo Reservoir described in **Section 6.3.2.2** are applicable to impacts associated with direct mortality of existing aquatic organisms. In summary, the loss of aquatic vegetation within Talbingo Reservoir resulting from direct mortality is considered negligible given the extensive area of similar habitat throughout the reservoir.

Submerged Timber

As discussed above, submerged timber is extensive throughout Talbingo Reservoir. All species of fish that are known to occur, or have the potential to occur within Talbingo Reservoir, may be found in and around submerged timber habitat. Although the importance of this habitat to aquatic fauna is well understood, it is widespread throughout the reservoir and any direct loss of this habitat within the excavated material placement area likely represent only a small area compared to the broader reservoir. Therefore, it is considered that any impacts to submerged timber in the excavated material placement area would have a negligible effect on aquatic biota.

Based on the receptors present, assessment of unmitigated risk levels for “Displacement/direct mortality of existing aquatic organisms” within Talbingo Reservoir range from Low to Moderate (**Table 6-5**). The residual risk to sensitive receptors, following the implementation of the mitigation measures identified in **Section 6.3.4**, would be Low (**Table 6-5**).

6.3.2.4 Indirect - Changes to water quality

The placement of excavated material within Talbingo Reservoir has the potential to significantly change water quality throughout the reservoir and impact aquatic ecology. As the composition of the excavated material would potentially contain large quantities of fines (< 43 micron diameter), this has the potential to remain suspended within the water column. Sediment deposition would also occur within and outside of the placement area. Four main impact pathways on water quality exist as a result of the placement of excavated rock within Talbingo Reservoir:

> Elevated concentrations of suspended sediment, some of which may adhere to and damage the gills and feeding apparatus of aquatic biota;

> Sedimentation resulting in the smothering of aquatic plants and habitat, resulting in die back of photosynthetic organisms and habitat modification;

> Increased turbidity resulting in changes in light penetration and behaviour of aquatic biota; and

> Changes in water quality, such as elevations in electrical condictivity (EC) and increased concentrations of metals released from the mobilised excavated material.

As excavated rock is placed into the reservoir, it would travel down the bed slope. Fine sediments would be released into the water column forming a turbid plume that would disperse through the reservoir. The extent of the plume would be minimised by the use of a silt curtain around the emplacement area, though the curtains will not extend to the bed of the reservoir. Modelling of the placement program has indicated that some suspended sediment would likely be carried past the curtain (EIS Appendix L, RHDHV Excavated Rock Placement Summary and RHDHV, 2019). Key associated stressors for biots include increases in total suspended sediments (TSS), turbidity, electrical conductivity, concentrations of aluminium and changes in pH.

Total Suspended Sediments and Turbidity

The maximum predicted TSS concentrations across the reservoir were modelled over the placement period and the following year (3 years in total) (EIS Appendix L, RHDHV Excavated Rock Placement Summary, RHDHV 2019). Modelling indicates that the maximum TSS concentration within the silt curtains surrounding the placement area is predicted to be high (up to 2,700 mg/L). Outside the placement area, it is predicted that TSS concentrations will be highest immediate adjacent to the Ravine Bay placement area and will decrease with increasing distance north along the reservoir, with the annual median surface TSS concentration decreasing from 18 mg/L in the Yarrangobilly Arm to 6 mg/L adjacent to the dam wall.

TSS concentrations in surface water would season due to seasonal differences in the extent of water. For example, the median surface TSS in the Yarrangobilly Arm is predicted to be 43 mg/L for the five warming months and 9 mg/L for the seven cooling months of the year. The median surface TSS adjacent to the dam wall is predicted to be 10 mg/L for the warming months and 3 mg/L for the cooling months. The maximum surface TSS concentrations are predicted to peak in the second half of the warming period and rapidly decrease as the reservoir cools but are predicted to remain above the very low background TSS concentrations in a large section of the reservoir. There is no default ANZECC / ARMCANZ (2000) TSS guideline value; however, based on conversion of TSS to turbidity, it is predicted that the TSS (and turbidity) will exceed the default guideline value in a number of locations throughout the reservoir at various times throughout the placement program (EIS Appendix L – RHDHV, 2019).

Data collected between 2018 and 2019 by Cardno indicates water clarity within Talbingo Reservoir is generally good, with turbidity often approximately 2 NTU (Cardno, 2019). The Ravine Bay Emplacement will take approximately 24 months to construct. TSS is expected to range between 3 mg/L and 80 mg/L and turbidity between around 20 NTU and 83 NTU, depending on location in the reservoir and the time of year. Surface TSS concentrations and turbidity are predicted to return to close to background levels within approximately 8 months of the completion of the Ravine Bay excavated material emplacement (EIS Appendix L – RHDHV, 2019).

EC, Aluminium and pH

Followin the commencement of the placement program, EC in the reservoir is predicted to exceed background EC in the reservoir and default guideline values until dilution and sediment deposition decreases the TSS concentrations significantly below 100 mg/L. Predicted exceedances would be marginal 55 µS/cm to 74 µS/cm compared with the default guideline values of 20 µS/cm to 30 µS/cm. EC exceedance is expected to be greatest within the placement area and reduce with increasing distance. At lower TSS concentrations (<100 mg/L), pH is expected to be within the default guideline values.

Based on the results of elutriate tests (that simulated the effect of suspended excavated rock particles on reservoir water quality) and hydrodynamic modelling results, the placement program may result in aluminium concentrations that exceed baseline and default guideline values close to the emplacement area. The ANZECC / ARMCANZ (2000) default trigger value for aluminium in slightly to moderately disturbed ecosystems (55 µg/L) may not be met immediately outside of the silt curtain around the placement area, though is expected to be met within 500 m from the silt curtain. Therefore, a mixing zone 500 m from the silt curtain would be required to meet the default guideline value for aluminium (EIS Appendix L, RHDHV Excavated Rock Placement Summary, RHDHV 2019).

Sedimentation

During placement excavated rock in the placement area would travel down the slope of the emplacement and deposit within the emplacement footprint. However, some of the suspended sediment may not settle immediately and a small proportion is expected to be dispersed out of the placement area and settle to the bed of the reservoir beyond the emplacement area. During construction, it is predicted that sediment deposition rates would be:

> Greater than 150 mm/year closest to the emplacement location;
> Between 7 mm/year and 45 mm/year in the southern half of the reservoir;
> Between 2 mm/year and 15 mm/year in the northern half of the reservoir; and
> Greater in shallow parts of the reservoir (i.e. reservoir edges) than in deeper parts.

Background sediment deposition rates in parts of the Yarrangobilly Arm have been estimated at 5 mm/year to 15 mm/year, while it is estimated that very little sediment deposition (<1 mm/year) currently occurs in the rest of the reservoir.

Elevated concentrations of suspended sediment and elevated turbidity and sedimentation from excavated material placement have the potential to impact on a number of aspects of the aquatic environment. These include.

> A decrease in photic depth;
> Reduced primary productivity;
> Decline in the distribution and abundance of aquatic vegetation;
> Changes in assemblage composition of aquatic vegetation;
> Smothering of sensitive aquatic habitat from deposition of suspended sediments; and
> Impacts on fish communities via;
  - Behavioural changes involving avoidance of plumes;
  - Diminished visual capacity when foraging and feeding;
  - Damage to gills due to the potential abrasive nature of the suspended sediment;
  - Smothering of spawning sites; and
  - Potential impact on environmental cues for spawning.

Currently, the photic depth (depth at which underwater light reduces to 1% of its surface intensity) within Talbingo Reservoir is typically shallower than about 10 m. Photic depth is predicted to decrease with increasing turbidity (**Table 6-3**).

Table 6-3 Relationship between photic depth and turbidity within Talbingo Reservoir (Cardno, 2019)

Turbidity (NTU)	Extinction Coefficient, *k*	Photic Depth Z_P
2	0.60	7.7
5	1.29	3.6
10	2.44	1.9
15	3.59	1.3
20	4.74	1.0

The relationship above has been compiled from existing conditions currently in the reservoir and does not taken into account any turbidity generated from the excavated material (Cardno, 2019), but it indicates of the level of change in photic depth that could potentially occur with increasing turbidity levels within the reservoir. As can be seen, a reduction in photic depth can occur at 20 NTU. During the placement of excavated material, in some areas, turbidity levels would be much greater than those reported above. Thus, photic depths could be expected to decrease further than presented in **Table 6-3** in these areas.

A reduction in photic depth would have implications for aquatic vegetation within the reservoir. Large, dense areas of exotic *Elodea* occur within Middle creek, Middle Arm and the Yarrangobilly Arm within the vicinity of the excavated material placement footprint, with these areas predicted to receive significant increases in turbidity from the excavated material placement. Mortality of these beds of macrophytes would be expected due to increased turbidity. Although these beds consist of mostly of introduced pest species, given their dense, widespread nature within these parts of Talbingo Reservoir, die and decompose to cause eutrophication with assocated reductions is dissolved oxygen concentrations.

A decrease in photic depth would also affect phytoplankton assemblages within Talbingo Reservoir and thus its primary productivity, which is the basis of aquatic food webs. The phytoplankton assemblages within the reservoir are generally diverse and abundant and they occur throughout the surface layers of the reservoir. These assemblages would account for a large proportionity of the primary productivity within the reservoir compared with macrophytes (as they cover a significantly greater volume of the entire reservoir, not just within its shallow margins) the decrease in photic depth from increased turbidity could have important implications on these assemblages. Due to the decrease in photic depth, the volume of water in which phytoplankton would reside would decrease substantially, and in some areas,virtually no photic zone would exist for a period of time. It would be expected that this would occur throughout much of the placement period due to the high turbidity within the reservoir.

Impacts of increases in turbidity on primary productivity have been well documented. Lloyd et al. (1987) reported that turbidity increases of 25 NTU reduced primary productivity by 13 5 to 50 % within shallow, clear water streams. Likewise, Davies-Colley et al. (1992) reported turbidity increases within New Zealand streams as low as 9 NTU were shown to reduce algal biomass by as much as 40 %.

Elevated suspended sediments have potential to harm fish, crayfish and other aquatic biota in the reservoir. Fine suspended particles (such as those that would be suspended due to placement of excavated rock) may adhere to the gill structures and feeding apparati of fish and crayfish and other aquatic organisms. This can result in asphyxiation and damage to these structures, increased energy expenditure, stress and potential mortality. Suspended sediments have been shown to result in deleterious effects on primary producers, zooplankton, benthic invertebrates and fish in lakes (see Donohue & Molinos, 2009, and references therein, for one of many reviews). Ecotoxicology investigations undertaken for this assessment using suspensions of the rock material that would be deposited in the reservoir by CSIRO (2019) indicated toxicity to species of phytoplankton (*Raphidocelis subcapitata*), zooplankton (*Ceriodaphnia dubia*) and a benthic macroinvertebrate (*Chironomus tepperi*). A second benthic macroinvertebrate (*Lumbriculus variegatus*) appeared relatively unaffected by the suspended material. It is noted that the turbidity associated with toxcity observed here were often far in excess of what would be occur outside of the placement area, though likely comparable with that which would be present within the silt curtains. The use of these findings to predict effects that may occur in the reservoir during placement is, however, hindered by the laboratory setting of the experiment. In particualr, the duration of the excotoxicology testing was no longer than 28 days, whereas in the reservoir sediments would be suspended for longer periods. Moreover, fish were tested in CSIRO (2019). More complex organisms such as fish would be expected to be more suseptable to the effects of suspended sediments. It is possible that fish and other organisms in the reservoir would experience chronic or, in some caases, acute, stress related to the predicted increases in suspended sediments.

Suspended sediment resulting from placement of excavated material ultimately would be deposited on the reservoir floor, with the potential to impact on aquatic habitats and associated biota. Modelling of bed thickness following spoil placement predicts that much of this sediment would settle along the shallow margins of the reservoir and within Ravine Bay, Middle Creek, Middle Arm, the lower Yarrangobilly River and upstream into the Tumut River Arm. In some places within Ravine Bay and Middle Creek, sedimentation from spoil placement would exced 150 mm (Appendix L, RHDHV Excavated Rock Placement Summary, RHDHV 2019).

Around the shallow margins of the reservoir, field surveys indicated that many bays and inlets had areas of submerged aquatic vegetation. Much of this vegetation is introduced (primarily *Elodea*), and can occurs in large densities. The deposition of suspended sediment in these areas would smother this vegetation and may lead to a decrease in distribution and abundance. Notwithstanding, loss of aquatic vegetation, whether exotic or native, could have flow on effects to species of fish and macroinvertebrates that utilise these areas for spawning and refuge.

Based on the receptors present, assessment of unmitigated risk levels for “Changes in water quality” range between Moderate and High. The residual risk to sensitive receptors, following the implementation of the mitigation measures identified in **Section 6.3.4**, would be Moderate (**Table 6-5**).

Sediment suspended in Talbingo Reservoir from placement of excavated material may also be transported through the Tumut 3 release to the Tumut River Catchment downstream of Talbingo Reservoir dam wall. The transport of mobilised sediments downstream of Talbingo Reservoir could also affect aquatic habitat and biota here. Water quality changes would be expected to be less than those within Talbingo reservoir and will be subject to further assessment as required.

6.3.2.5 Impacts on KFH, Threatened Species and EECs

The relatively small areas of submerged macrophytes and wooded debris occurring within the excavated material placement area within Ravine Bay would be permanently lost as a result of the proposed excavated material placement program. Similar areas of submerged aquatic vegetation, however, occur throughout Talbingo Reservoir. As such, destruction of areas within the excavated material placement area would be unlikely to significantly affect fish or invertebrates as they would seek similar habitat elsewhere.

As noted in **Section 5.3.5**, a self-sustaining and broadly distributed population of Murray crayfish, occurs within Talbingo Reservoir, although this appears to have been subject to recent declines, potentially due to excessive macrophyte growth (Zukowski & Whiterod, 2019). Surveys have found low numbers of Murray crayfish in areas in and around the proposed excavated rock placement area. As excavated material placement would take place from the shoreline to a depth of some metres below MOL, the placement area would likely include habitat in the depth range where Murray crayfish are known to occur and build burrows (i.e. between 2 m and 17 m). As Murray crayfish have relatively small home ranges and low dispersal abilities (NSW DPI, 2019c), they would be vulnerable to both direct impacts of habitat degradation and indirect impacts to water quality (increased turbidity, suspended sedminets and sedimentation). In particular, Murray crayfish are considered to be intolerant to low levels of dissolved oxygen and in extreme cases, this has led to local population depletion (NSW DPI, 2019c). Targeted sampling would therefore be done in and around the proposed placement area to collect Murray crayfish potentially occurring there prior to the commencement of emplacement. This would be implemented as outlined in the AqHMP.

The risk of trout cod occurring within the footprint of the excavated material placement area at the time of excavated material placement would be extremely low. In the highly unlikely event that any individuals were subjected to direct impacts of excavated material placement, it is possible that they would temporarily experience indirect, sub-lethal effects but that they would most likely move to other areas of the reservoir or areas within feeder creeks and river arms that are not subjected to high levels of turbidity. Trout cod are currently stocked into Talbingo Reservoir, thus any impacts on this species from excavatued rock placement would be short term as individuals will be replaced by subsequent restocking.

Talbingo Reservoir is considered a type 1 (highly sensitive) KFH as per Fairfull & Witheridge (2003). Thus, the emplacement area and areas of substantial settlement of sediments outside the silt curtain would cause an impact of loss of a small portion of type 1 KFH relative to Talbingo Reservoir. No EECs have been identified to occur within Talbingo Reservoir.

6.3.2.6 Key Threatening Processes

Excavated material placement would have potential to facilitate the following KTPs within Talbingo Reservoir:

> Degradation of native riparian vegetation along New South Wales water courses (FM Act); and

> Removal of large woody debris from New South Wales rivers and streams (FM Act).

The area of vegetation adjacent to the reservoir that is likely to be directly impacted by placement activities will be very small relative to the total area of shoreline vegetation around Talbingo Reservoir. Similarly, the area of wooded debris occurring within the placement footprint is small relative to the total area in the reservoir. The loss of these areas would not be expected to impact the broader aquatic ecosystem within the reservoir

6.3.3 Tantangara Reservoir

6.3.3.1 Impacts on Aquatic Habitats and Biota

The placement area in Tantangara Reservoir for dredge spoil and excavation material would be in the same location and on land that is between the MOL and FSL and stored within discrete cells. During the construction period Snowy Hydro would limit the upper reservoir level to the MOL, effectively ensuring that the placement area comprises terrestrial and not aquatic habitat. On this basis no further assessment in terms of aquatic ecology is required for the construction phase (but is considered as part of the operational phase (**Section 7**) when water levels would vary up to FSL.

The use of discrete cells located above the MOL presents an extremely small risk in terms of aquatic ecology during construction. Notwithstanding this assessment, environmental management should be considered in the event of some (unlikely) failure and incorporated into the relevant management plans (e.g. the AqHMP and DEMMP).

6.3.4 Mitigation Measures and Residual Risks

Mitigation measures outlined in **Table 6-4** would be implemented to control construction related risks from edge push placement.

Table 6-4 Mitigation measures to control risks from edge push placement.

Mitigation Code	Description
AE08	A silt curtain will be deployed to minimise the spread of turbid water/suspended solids beyond the footprint, where practicable

AE09	Contaminated sediments and soils posing a risk to aquatic habitats will be managed in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP)
AE01	An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; and • include a program to monitor and report on the effectiveness of these measures.

Provided that the mitigation measures outlined above are implemented, it is expected the ecological risks from excavated material placement would be either moderate or low (**Table 6-5**). Note that this assessment is based on the assumption that impacts related to excavated material placement would be confined to within the reservoirs and would not impact multiple catchments.

Table 6-5 Qualitative risk assessment of likelihood and consequences of excavated material/excavated rock placement before and after proposed mitigation. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Loss/ modification of aquatic habitat due to smothering	Talbingo Reservoir	Threatened aquatic species-Trout cod	Possible	Insig	Low	Possible	Insig	Low
		Threatened aquatic species-Murray crayfish	Possible	Minor	Mod	Unlikely	Minor	Low
		Native aquatic species	Possible	Insig	Low	Possible	Insig	Low
		Salmonids	Possible	Insig	N/A	Possible	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
Displacement/ direct mortality of existing aquatic organisms	Talbingo Reservoir	Threatened aquatic species-Trout cod	Possible	Insig	Low	Possible	Insig	Low
		Threatened aquatic species-Murray crayfish	Possible	Minor	Mod	Unlikely	Minor	Low
		Native aquatic species	Possible	Insig	Low	Possible	Insig	Low
		Salmonids	Possible	Insig	N/A	Possible	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	NA	NA	NA	NA	NA	NA

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
		Native aquatic species	NA	NA	NA	NA	NA	NA
		Salmonids	NA	NA	NA	NA	NA	NA
		Planktonic assemblages	NA	NA	NA	NA	NA	NA
Changes to sediment quality within the proposed placement areas	Talbingo Reservoir	Threatened aquatic species-Trout cod	Possible	Minor	Mod	Unlikely	Insig	Low
		Threatened aquatic species-Murray crayfish	Possible	Minor	Mod	Unlikely	Insig	Low
		Native aquatic species	Possible	Minor	Mod	Unlikely	Insig	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
Changes to water quality	Talbingo Reservoir	Threatened aquatic species-Trout cod	Likely	Minor	Mod	Likely	Minor	Mod
		Threatened aquatic species-Murray crayfish	Likely	Mod	High	Likely	Minor	Mod
		Native aquatic species	Likely	Mod	High	Likely	Minor	Mod
		Salmonids	Likely	Mod	N/A	Likely	Minor	N/A
		Planktonic assemblages	Likely	Minor	Mod	Likely	Minor	Mod
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A

6.4 Surface Infrastructure and Utilities

6.4.1 Description of Impacting Processes

Surface works that have potential to impact upon the aquatic environment during Main Works would include:

> Access road construction and upgrades (including bridges and other crossings);

> Accommodation camps and construction compounds;

> Subsurface utilities;

> Substations and power connections;

> Ancillary construction facilities (including concrete batching plants, crushing plants, laydown areas, stockpile areas, water and wastewater services and water management infrastructure);

> Wastewater outflows; and

> Installation of the fish screening system for releases from Tantangara Dam River Outlet Works (ROW) and the Murrumbidgee-Eucumbene Tunnel (M-E Tunnel) and a barrier to upstream fish movement on the Upper Tantangara Creek

Surface works would be located near intakes within Talbingo and Tantangara reservoirs and Lobs Hole and construction staging areas within the plateau region of the project area (**Figure 1-1**). Infrastructure and utilities would also transect parts of the Yarrangobilly River, Upper Tantangara Creek, Upper Murrumbidgee and Lake Eucumbene catchments. General information relating to habitat condition and species distributions across these catchments is in **Section 5.5**.

6.4.1.1 Roads and bridges

New access roads are proposed to be constructed and existing access tracks upgraded to provide access to the work sites. The roads will be used to service construction yards, accommodation camps and construction areas. Roads that provide access to permanent infrastructure would remain after construction. Some of these roads would cross small ephemeral waterways whereas some would cross larger perennial creeks and require a new or upgraded permanent waterway crossing. This would include the following:

> Upgrade of existing crossing of Marica Trail over Eucumbene River;

> Upgrade of permanent crossing of Tantangara Road over Nungar Creek;

> New permanent culvert on Quarry Trail over Kelly's Plain Creek to replace existing twin culvert; and

> New permanent crossing culvert over unnamed ephemeral watercourse draining into Talbingo Reservoir.

6.4.1.2 Accommodation camps and construction compounds

Several temporary construction compounds and camps would be constructed as part of the main works, including the Talbingo Adit and Construction Compound, Lobs Hole Accommodation Camp and Construction Compound, Marica Construction Compound, Tantangara Intake and Construction Compound and Tantangara Accommodation Camp and Adit (**Figure 1-1**). The cable yard proposed at the ECVT portal would be permanent. Both temporary and permanent infrastructure could impact on several unnamed ephemeral watercourses and / or drainage lines.

6.4.1.3 Subsurface utilities

Subsurface utilities would include permanent communications and power cables along routes from Talbingo to Tantangara intake structures and construction sites. From Tantangara Intake to Cabramurra (via Dry Dam and Link Road/Kings Cross Road) the subsurface utilities would include communication cables only. Subsurface cable routes would transect numerous unnamed ephemeral watercourses and / or drainage lines and perennial watercourses including the Yarrangobilly River, Lick Hole Gully, Cave Gully, Wallaces Creek, Eucumbene River, Gooandra Creek, Tantangara Creek, Nungar Creek, Kelly's Plain Creek, Boggy Plain Creek, Kiandra Creek, Chance Creek, Hayes Gully and Three Mile Creek. Cables would be trenched and buried in conduits within access roads. Where cable routes cross watercourses they would be installed in a manner that does not obstruct flow and minimises habitat disturbance with 3rd order permanent waterways to be underbored or may, where feasible, be integrated with new or existing placed within existing crossing infrastructure such as bridges. Several unnamed ephemeral watercourses and / or drainage lines could be be affected by such facilities (**Figure 1-1**).

6.4.1.4 Wastewater

Varying sources of wastewater would be generated during the different stages of the project with the majority being produced during the construction phase. The temporary sources of wastewater during construction would be domestic sewer (e.g. from temporary accommodation camps), tunnel seepage, construction wastewater and construction yard stormwater.

There are several direct and indirect pathways and mechanisms through which the surface infrastructure and utilities described have potential to affect aquatic habitats and associated flora and fauna within the project area. These include:

> Direct - removal/modification of habitat and associated biota at infrastructure locations;

> Direct – temporary obstruction to fish passage;

> Direct – changes to water quality from point source discharges;

> Indirect - changes to water quality from diffuse surface run-off; and

> Indirect – spread of aquatic weeds and pest fish.

Potential impact pathways would be broadly managed via the Water Management Plan. Impacts of surface works would primarily be controlled via the methodologies outlined in the Erosion and Sediment Control Plan (ESCP) and would be supported by other sub-plans.

6.4.1.5 Installation of Fish Barriers

The design of Snowy 2.0 includes the installation of fish barriers to prevent the potential movement of fish into secondary catchments upstream and downstream of Tantangara Reservoir, should they be transferred from Talbingo Reservoirs (**Section 7.2.3**).

An instream barrier would be installed in Upper Tantangara Creek just above the waterfall (that currently prevents salmonids from accessing this section of watercourse) upstream of Alpine Creek Trail. This nominated barrier site is located in a relatively narrow gorge with a steep gradient and bedrock channel substratum. The barrier would be located downstream of the known population of stocky galaxias. This was identified as the only suitable location for the barrier (Raadik, 2019). The barrier has been designed to prevent the potential movement of climbing galaxias into the habitat of the stocky galaxias. The barrier would prevent fish from moving upstream. The construction of the barrier could be associated with localised impacts to stocky galaxias and Reik's crayfish, which may also occur in this section of creek, and Reik's crayfish and salmonids immediately downstream of the waterfall. Construction of the barrier would involve temporary flow diversion during construction (for excavation, concreting and removal of excavated material). Potential impacts to these species could arise due to:

> Displacement of stream habitat beneath the footprint of the structure and modification of flowing watercourse habitat due to impoundment of water behind the weir structure. The structure would sited and constructed so that habitat displacement and modification would occur downstream of the preferred habitat of stocky galaxias; and

> Mobilisation and release of sediments into the watercourse during construction.

The structure would be designed and constructed so that habitat displacement and stream modification would occur downstream of the known preferred habitat of stocky galaxias.

A screening system would be installed to filter all water released through Tantangara Reservoir dam ROW and the M-E Tunnel. The system would be located within proximity of Tantangara Reservoir dam wall. The screens would prevent passage of all life stages of redfin perch, eastern gambusia and climbing galaxias. Key construction activities would include:

> Water level management and site works to facilitate a dry construction area;

> Installation of temporary water diversion piping to maintain environmental flows down the Murrumbidgee River during construction;

> Excavation and extraction of the rock embankment to allow room for the facility;

> Construction of the screening structure and mechanical fit out;

> Modification works to link the new screening system to the existing releases; and

> Demobilisation and commissioning.

Following construction, ongoing maintenance of the screening system may require annual draining of sections of the facility for visual inspection and other general maintenance activities such as replacing gearbox oil, repairing/cleaning screens and calibration of sensors etc.

Potential impacts associated with the construction of the screening system could arise with displacement of reservoir habitat and mobilisation of sediments during excavation.

Aside from the (intentional) barriers to movement of target fish, these barriers may also create ongoing barriers to movement of other species of fish. Although associated impacts are likely to be insignificant. The barrier created in the Upper Tantangara Creek is likely to be largely redundant given the existing natural barrier created by the waterfall, which is almost certainly not passable by Reik's crayfish or salmonids. The barrier installed on the M-E Tunnel would also eliminate the existing artificial connection for fish between Tantangara Reservoir and Lake Eucumbene. This is not expected to result in detrimental impacts to native species of fish or salmonids. The barrier installed at Tantangara Reservoir dam wall may conceivably affect movement of native species of fish from Tantangara Reservoir to the Mid Murrumbidgee River, although impacts to the native species present in both areas (mountain galaxias and Reik's crayfish) are likely to be insignificant since neither species is known to undertake migrations over long distances. In any case, there is likely to be minimal current movement of these species through

Tantangara dam wall given each prefers flowing habitat and would be unlikely to occur in the vicinity of the Tantangara dam ROW intake.

6.4.2 Impacts on Aquatic Habitats and Biota

6.4.2.1 Direct - removal/modification of habitat and associated biota at infrastructure locations

The area throughout the study area likely to be impacted by the installation of surface infrastructure and utilities will be very small relative to the total area of available habitat. Proposed access roads have generally been aligned to minimise direct impacts to aquatic habitat and biodiversity and to avoid the construction of new waterway crossings. In general, an exclusion buffer would be applied for road construction either side of a river (except for where bridges or other crossing structures are nominated), to minimise potential impacts to aquatic habitats.

Road upgrades and extensions near watercourses would result in the permanent loss of a small area of riparian and / or instream vegetation where bridge piers or culvert boxes are located and the road alignment requires cut or fill beyond what is already disturbed by an existing crossing. The clearing of vegetation on the river banks could also indirectly affect aquatic biota as riparian vegetation provides a source of food and shelter for aquatic macroinvertebrates and fish. Riparian vegetation is also a source of instream habitat in the form of wood debris (snags) and detritus, which provides shading and stabilises banks.

Given the small footprint of the crossing sites compared with extensive similar riparian and instream habitat along the Eucumbene River, Nungar Creek, Kelly's Plain Creek and Talbingo Reservoir, the extent of habitat loss / modification would be minor. The restoration of any aquatic and riparian habitat disturbed as part of infrastructure construction would be undertaken in accordance with the Rehabilitation Management Plan and AqHMP.

Communications cable routes will transect numerous ephemeral waterways within the plateau region connecting Cabramurra to various accommodation camps and key construction sites. Crossings of the Yarrangobilly River and Wallace's Creek will be established as part of the Exploratory Works, however, other locations where cable routes would cross larger perennial waterways would include the Eucumbene River, Gooandra Creek, Tantangara Creek, Nungar Creek and Kelly's Plain Creek. Provided that cable routes are underbored below the creeks or integrated with new or existing crossing infrastructure such as bridges, with erosion and sediment controls in place, then the disturbance at these locations would be short term and highly localised.

Wastewater including process water, will be treated and discharged through dedicated outlets at Talbingo and Tantangara reservoirs as required. Wastewater generated at remote sites (such as Marica) would collected and transported to either a project facility, or suitable external facility, for treatment.

As described in (Chapter 6.2, Snowy 2.0 Main Works EIS), clean runoff would be diverted around sites and discharged into existing creeks including energy dissipation measures where necessary to prevent erosion whereas runoff from construction sites will be discharged via sediment basins.

The area of permanent habitat displacement (upstream of the Tantangara Creek barrier) and flow modification (due to inundation of flowing water) represents a small section of upper Tantangara Creek. Aside from stocky galaxias, Reik's crayfish may occur in Upper Tantangara Creek. Given the relatively small area of habitat affected by the installation of the barrier, and the abundance of comparable habitat present in the Upper Murrumbidgee River Catchment, associated impacts to Reik's crayfish is likely to be insignificant. As noted by Raadik (2019), the proposed location of the barrier, although inside the area considered to be habitat for stocky galaxias, is located in a zone in which very few individuals due to the extensive areas of bedrock and fast flows, thereby minimising potential construction impacts on the population.

Similarly, the relatively small area of reservoir habitat (sloping rock bank and any unconsolidated sand and gravel bed substrata) that would be displaced or modified due to construction of the screening system in Tantangara Reservoir would have negligible consequences for aquatic species in the reservoir.

Based on the receptors identified, assessment of unmitigated risk from removal/modification of habitat and associated biota ranged from low to moderate across the catchments potentially affected. The residual risk, following the implementation of the mitigation measures identified in **Section 6.4.5** would be low (**Table 6-7**).

6.4.2.2 Direct – temporary obstruction to fish passage

Upgraded access roads would require upgrade of existing crossings or construction of new crossings over third order perennial watercourses including Eucumbene River (Lake Eucumbene catchment), Nungar Creek, Kelly's Plain Creek (Upper Murrumbidgee catchment) and an unnamed 1st order watercourse draining into Talbingo Reservoir. These are generally considered to be Class 1 (major fish habitat) waterways containing type 1 KFH including reaches in the vicinity of these crossings. The exception is at the Kelly's Plain Creek crossing which is a Type 2 KFH. All crossing locations are relatively undisturbed with pebble, gravel or cobble beds and in-stream and fringing emergent macrophytes. Where permanent crossings are proposed to be constructed over these third order waterways, works would have potential to temporarily obstruct the passage of fish and mobile macroinvertebrates. This could affect migrating fish and restrict their ability to breed and spawn. When energy is expended to negotiate barriers, delayed or missed spawning events may occur (Fairfull & Witheridge, 2003).

Several non-threatened native species are likely to occur in the Upper Eucumbene River (Lake Eucumbene Catchment), Nungar Creek and Kelly's Plain Creek (Upper Murrumbidgee Catchment) including locations for crossing upgrade or replacement. Reik's crayfish may occur at all three propsoed crossing locations. Common yabbies and mountain galaxids may also occur at the proposed Nungar and Kelly's Plain creek crossings. Rainbow and brown trout are likely to occur in Nungar and Kelly's Plain creeks. Reik's crayfish and common yabbies have migratory stages in their life history which could be temporarily affected by barriers to fish passage. These species are ubiquitous across various habitat types (ephemeral streams, reservoirs, swamps, farm dams) and can survive out of water for extended periods, therefore be resilient to temporary barriers to movement. Mountain galaxias have small home ranges and do not migrate.

The crossing site at Talbingo Reservoir has the potential to provide habitat for several non-threatened native species and threatened Murray crayfish and trout cod when this area is inundated by the reservoir. Although Murray crayfish do not migrate as part of their lifecycle, construction of a crossing culvert could affect local foraging behaviour or restrict access to food resources downstream in the reservoir. Construction works at this site would therefore require site specific management to be outlined in the AqHMP. Pre-construction clearance surveys would be undertaken if warranted. Trout cod have been stocked into Talbingo Reservoir and could occur at the proposed crossing, when it is inundated by the reservoir but would not be expected to utilise the ephemeral waterway. Due to the likely transitory nature of their use of this area and the fact their presence is due to stocking (and they do not form a self-sustaining population), no specific management action would be necessary.

Numerous unnamed, ephemeral, first and second order tributaries that occur across the project area would also be transected by roads, although the aquatic habitat value of these small watercourses would be limited as they are often dry apart from following rainfall events and runoff from snow melt. Even following rainfall, such ephemeral watercourses would be unlikely to provide significant habitat for native fish or macroinvertebrates and the risk of obstructing native fish passage or fragmenting populations is low.

All practicable measures to minimise temporary waterway obstructions during the upgrade or construction of bridges and culverts. Where structurally practical, bridges over third order creeks and rivers would be designed and constructed to span the width of the watercourse with abutments located beyond the extent of normal (non-flood) flows in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge, 2003).

Where practical, construction works within the channel of a permanent waterway containing type 1 or 2 KFH would allow some flow at all times and be staged to minimise the total disturbance at any given time to maintain fish passage. Any flow diversion barriers and instream sediment control barriers would be removed as soon as practicable and rehabilitated as described in the Rehabilitation Plan.

Communications

It is understood that all subsurface cables would be placed in accordance with Snowy Hydro specifications into trenches that are a minimum depth of 1200 mm. Where these cross 3rd order or higher permanent waterways cables would be installed using underboring or may, where feasible, be integrated with new or existing crossing infrastructure such as bridges, to minimise disturbance to the water course.

Overall, based on the receptors present, assessment of unmitigated risk from temporary obstruction to fish passage was moderate across the catchments potentially affected. The residual risk, following the implementation of the mitigation measures identified in **Section 6.4.5** would be low (**Table 6-7**).

Fish barriers

Temporary flow obstruction associated with construction of the fish barrier on upper Tantangara Creek would not be expected to affect stocky galaxias or Riek's crayfish as neither are considered migratory. Neither the Tantangara Reservoir dam ROW or the M-E Tunnel are expected to provide major conduits for fish. As such, the impact of the obstruction of fish passage through these structures is considered to be insignificant.

6.4.2.3 Direct – changes to water quality from point source discharges

Temporary wastewater discharge outlets would be constructed at each of the reservoirs. Given the location in the Kosciuszko National Park, very high standards of water quality would be maintained. Discharges will include groundwater inflows into the tunnel during excavation. A peak inflow of approximately 160 L/s is expected to enter the tunnel void. This water would need to be collected and removed from the tunnel to enable construction to continue. Any water not used for construction activities would need to be discharged. The quality of this water will depend on the quality of groundwater inflows and any degradation of water quality that could occur due to constructon activity and potential exposure to potentially acid forming (PAF) material. Groundwater inflows are likely to have elevated EC and concentrations of some nutrients greater than in the reservoirs. Concentrations of boron may also be elevated. Tunnel construction activities also have the potential to result in elevated concentrations of suspended sediments, metals, hydrocarbons and other contaminants.

With the exception of uncontrolled stormwater discharge, all wastewater would be treated and would comply with the relevant surface water quality guidelines and discharge limits as set out in the WMP. Where possible, process water would be reused for TBM operations, dust suppression and greywater to reduce the flow discharged into reservoirs. After construction is complete, the amount of wastewater would significantly reduce with the sources of wastewater being largely from dry tunnels/powerhouse seepage and MAT control building sewerage.

Process water and waste water systems have been designed to ensure that water is treated to reasonable and feasible standards prior to discharge (Chapter 6.2 in the Snowy 2.0 Main Works EIS). The characteristics of discharge water would likely include pH between pH 6.5 and pH 8.0, turbidity < 25 NTU and concentrations of suspended solids below 5 mg/L. Concentrations of nutrients and metals may slightly exceed water quality objectives. EC would not be reduced by treatment and water with a likely range of EC of up to 300 µS/cm and up to 1,800 µS/cm may be discharged into Tantangara Reservoir and Talbingo Reservoir, respectively. The EC of discharged water would usually be lower than these upper values. The mixing zone for these discharges is expected to be within tens of meters of either discharge location.

Given expected changes to water quality in the reservoir would be restricted to within the relatively small mixing zone, and providing that all construction related discharge water is monitored throughout the construction phase and meets the requirements of the WMP, detrimental impacts to the receiving aquatic environment are not expected. Overall, based on the receptors present, assessment of unmitigated risk from changes to water quality from point source discharges would be low for both reservoirs. The residual risk, following the implementation of the mitigation measures identified in **Section 6.4.5** would remain as low (**Table 6-7**).

6.4.2.4 Indirect - changes to water quality from diffuse surface run-off

The construction of new roads, accommodation camps and construction staging sites would result in the replacement of previously vegetated surface soil with impervious hard stand surfaces. By increasing the amount of impervious surfaces, there is potential for:

> An increase in the volume of stormwater run-off entering watercourses within the associated watershed;

> Increased sediment loads entering watercourses leading to turbidity, suspended sediments and potential for sedimenatation and formation of sand bars; and

> Loss of groundwater filtration and reduced flows d) input of warmer water and temperature increases; and

> Erosion and scour of stream banks as a result of increased flows (Brabec et al., 2002).

Hydrocarbons and metals have potential to accumulate on road and hardstand surfaces (particularly in staging areas where heavy plant and equipment are used), hence there is a pathway for contaminants to enter waterways following mobilisation such as during rainfall. Inputs of warmer water from hard stand surfaces may impact on the behaviour of fish and macroinvertebrates which are often dependent on temperature changes as spawning cues. Warmer water also typically has lower concentrations of dissolved oxygen. If not managed appropriately, a combination of these processes may lead to degraded stream and watershed health and diversity of fish and macroinvertebrates.

Based on the surface water quality impact assessment the overall increase in effective impervious area of affected watersheds wouldl be relatively small (see Water Management Report in EIS). All roads and hardstand areas would be designed and constructed with erosion and sediment controls incorporated to reduce the impact on the surrounding environment. Outfalls from road table drains would be positioned to avoid large concentrated surface water flows. Road drainage would be provided in accordance with the WMP.

Standard erosion and sediment controls as outlined in the WMP would also prevent the release of sediments into upper Tantangara Creek during construction of the fish barrier. The use of appropriate standard sediment and water quality controls in Tantangara Reservoir during construction of the screening system would also minimise changes to water quality outside of the construction area.

Temporary roads would be rehabilitated post construction in accordance with the Rehabilitation Management Plan. Based on the receptors present, assessment of unmitigated risk from changes to water quality from diffuse surface run-off would be low across the reservoirs and catchments potentially affected. The residual risk, following the implementation of the mitigation measures identified in **Section 6.4.5** would remain as low (**Table 6-7**).

6.4.2.5 Indirect – spread of aquatic weeds and pest fish

Heavy plant, vehicles and barges operating in and around waterways during construction of roads, utilities and infrastructure have potential to act as vectors for a range of aquatic weeds and pest fish if not properly managed. *Elodea*, occurs in Talbingo and Tantangara reservoirs and may be present in creeks and streams throughout the project area (**Annexure B**). As aquatic plants like *Elodea* grow and spread via fragmentation, these are easily transported in water. Pest fish including redfin perch, eastern gambusia and wild goldfish have also been recorded in the Yarrangobilly River Catchment, but not in the Upper Tantangara or Upper Murrumbidgee catchments. Fish eggs therefore have potential to be spread if they come in contact with vectors (e.g. excavators) which may be operating across multiple catchments and reservoirs. Eastern gambusia and wild goldfish are also not currently found in Tantangara Reservoir, the Upper Tantangara or Upper Murrumbidgee catchments. The introduction of pests to these catchments could impact on threatened species such as the stocky galaxias (Upper Tantangara Creek) and native species such as the mountain galaxias in the Upper Murrumbidgee River Catchment.

Preventing the spread of aquatic weeds and pest via vehicle and plant movements will be managed via measures outlined in the Weed, Pest and Pathogen Management Plan. Based on the receptors present, assessment of unmitigated risk from the spread of aquatic pests would range from low to high across the catchments potentially affected. The residual risk, following the implementation of the mitigation measures identified in **Section 6.4.5** would be moderate (**Table 6-7**).

6.4.3 Impacts on KFH, Threatened Species and EECs

Construction of surface infrastructure and utilities has the potential to affect both Talbingo and Tantangara reservoirs (type 1 and 2 KFH respectively) and KFH across the Yarrangobilly River, Lake Eucumbene, Upper Tantangara Creek and Upper Murrumbidgee Catchments, all which support substantial type 1 KFH. In the absence of mitigating controls, the cumulative effects of habitat removal and disturbance, impediment to movement of fish and macroinvertebrates, diffuse surface water run-off and point source inputs of wastewater have potential to impact on threatened species known or potentially occurring within the reservoirs and watercourses of the project area. These could include Murray crayfish and trout cod (Talbingo Reservoir and Yarrangobilly River). Stocky galaxias also occur in the Upper Tantangara Creek Catchment, however, these would be geographically isolated from the direct downstream impacts of surface infrastructure construction, (particularly those associated with crossing and communications routes that transect watercourses) as these will be downstream and physically isolated from the known stocky galaxias population by a significant waterfall. Although the construction of the fish barrier in Tantangara Creek would displace, modify and isolate short sections of the lower watercourse, this area appears to provide sub-optimal habitat for stocky galaxias, where very few individuals are usually present due to the extensive areas of bedrock and fast flows (Raadik, 2019). The total length of creek that would be affected is also only a small proportion of Upper Tantangara Creek. Impacts to water quality that may affect stocky galaxias are not expected as works would be downstream of the only known population. In any case, sediment and erosion controls would be implemented in accordance with the WMP. Potential impacts from diffuse water pollution e.g. increased surface run-off on threatened species would be low given the road design and sediment and erosion controls that would be in place.

The aquatic ecosystem of the Eucumbene River is part of the Snowy River EEC (**Section 5.6.2**) which has the potential to be indirectly impacted by uncontrolled surface run-off and temporary obstruction to fish passage on the Eucumbene River (Lake Eucumbene Catchment). The diffuse effects of surface run-off would be managed through standard erosion and sediment controls and the footprint of works around the bridge upgrade at the Marica Trail crossing over the Upper Eucumbene River would be small and short term. The overall risk to the native aquatic fauna and flora of this part of the Snowy EEC is manageable through the mitigation measures outlined in **Section 6.4.5**.

6.4.4 Key Threatening Processes

Construction of surface infrastructure and utilities would have potential to facilitate the following KTPs across the identified catchments:

- Degradation or native riparian vegetation along New South Wales water courses (FM Act);
- Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act);
- Introduction of fish to waters within a river catchment outside their natural range (FM Act);
- Removal of large woody debris from New South Wales rivers and streams (FM Act); and
- Loss and degradation or native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act).

As discussed in the preceding sections, the potential impacts associated with these processes can largely be managed through the mitigation measures set out below.

6.4.5 Mitigation Measures and Residual Risks

Mitigation measures outlined in **Table 6-6** would be implemented to control construction related risks from surface infrastructure and utilities.

Table 6-6 Mitigation measures to control risks from surface infrastructure and utilities.

Mitigation Code	Description
AE10	Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure construction to manage impacts of diffuse surface run-off on receiving watercourses
AE11	Rehabilitation of temporary roads and areas used for construction will occur in accordance with the Rehabilitation Plan
AE02	Bridges or culverts would be designed and constructed in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge 2003).
AE03	Construction works within the channel of a permanent waterway with type 1 or 2 key fish habitat would allow some flow to maintain fish passage at all times and be staged to minimise the total disturbance at any given time.
AE12	Where possible, an exclusion buffer will be applied for road construction either side of a river except where bridges or other crossing structures are required.
AE13	Procedures for the management of woody debris disturbed during construction of bridges or other waterway crossings would be outlined within the AqHMP;
AE14	Where cable routes intersect permanent waterways containing type 1 or 2 key fish habitat, construction will be carried out in a manner that does not obstruct flow and minimises habitat disturbance

AE15	Wastewater, including tunnel process water, will be treated and released in accordance with the measures specified in the Water Management Plan
AE16	Wastewater outlets would be designed and positioned to minimise the footprint of hard bank engineering and prevent bank scouring and erosion
AE04	A Weed, Pest and Pathogen Management Plan will be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.

Provided that the mitigation measures outlined above are implemented, the overall effects of surface infrastructure and utilities on sensitive receptors within the reservoirs and other affected waterways would be low to moderate (**Table 6-7**).

Table 6-7 Qualitative risk assessment of likelihood and consequences of surface infrastructure and utilities construction before and after proposed mitigation. L=Likelihood of occurrence; C = Consequence of occurrence. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic.

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Direct - removal/modification of habitat and associated biota at infrastructure locations	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Yarrangobilly River	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Murrumbidgee River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
	Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Rare	Minor	Low	Rare	Minor	Low
		Native aquatic species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Possible	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
Direct – temporary obstruction to fish passage	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Minor	Mod	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Minor	Low
		Native aquatic species	Possible	Minor	Mod	Unlikely	Minor	Low
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Murrumbidge e River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Minor	Mod	Unlikely	Minor	Low
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Minor	Mod	Unlikely	Minor	Low
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Possible	Minor	Mod	Unlikely	Minor	Low
		Native aquatic species	Possible	Minor	Mod	Unlikely	Minor	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
Direct – changes to water quality from point source discharges (i.e. waste water outlets)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Indirect - changes to water quality from diffuse surface run-off	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Yarrangobilly River	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Upper Murrumbidge e River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insign	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
Indirect – spread of aquatic weeds and pest fish	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	Possible	Insig	N/A	Possible	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Yarrangobilly River	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	NA	Unlikely	Insig	NA
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Murrumbidge e River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	Possible	Insig	NA	Unlikely	Insig	NA
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Possible	Major	High	Unlikely	Major	Mod
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A

6.5 Tunnel Excavation and Groundwater Drawdown

6.5.1 Description of Impacting Processes

Excavation of the tunnel would result in the interception and disturbance of aquifers within the path of its alignment (see Chapter 6 of the Snowy 2.0 Main Works EIS). Once intercepted, groundwater within these aquifers could flow into the tunnel void. The volume of inflow depends on factors such as the progress of excavation and rock porosity (peak inflow of approximately 160 L/s is expected). The inflow of this water would result in the depressurisation of aquifers and associated reductions in water tables and baseflow in watercourses above and adjacent to the tunnel alignment. Depending on the amount of drawdown, there could be a drying of stream reaches leading to loss of aquatic habitat, associated biota and loss of connectivity upstream of the water loss. Tunnelling is not expected to result in fracturing of bedrock in creek channels or any associated flow diversions.

Reduced surface flow in these watercourses could result in the following impacts to aquatic ecology:

> Losses or reductions in populations of aquatic biota (such as fish, crayfish, other macroinvertebrates and aquatic plants) due to loss or reduction in the availability of aquatic habitat. This could occur due drying of stream reaches, reductions in pool water levels during periods of reduced or no flow following the evaporation of seepage of water from pools. Reductions in flow may also reduce the availability of flowing riffle habitat for associated biota;

> Impacts to aquatic biota due to reductions in connectivity of aquatic habitat. This could occur at the relatively small scale of individual reaches and pools if flow is not maintained between pools that would otherwise be connected by flowing water. At a relatively larger spatial scale, sections of watercourse (each containing multiple pools and other aquatic habitats such as riffles) could become disconnected. Reduced habitat connectivity could limit the ability of aquatic biota to access different habitats they may require during different life stages (e.g. spawning migration of trout) and / or refuge and feeding. This could also result in reduced population sizes of associated biota;

> Changes in flow regimes in affected watercourses could impact aquatic biota that are influenced by changes in flow, for example, high flows may trigger migration and spawning in some species. It is possible also that reduced flows over time may result in the build-up of sediment in affected watercourses as less material is transported downstream, resulting in infilling of interstices in the substratum and habitat modification; and

> Impacts to aquatic biota due to impaired water quality in watercourses associated with reduced flow. This would likely be most evident in disconnected pool habitat with the potential for elevated temperatures and reduced concentrations of dissolved oxygen particularly during summer.

Modelling was undertaken to predict the reductions in baseflow and surface flow that would occur at selected sites in watercourses downstream of the tunnel alignment (**Table 6-8**)(EMM 2019a – Appendix J). Modelling incorporated a conservative approach of simulating all excavations as fully drained and unlined. This scenario does not consider actual design, management or mitigating activities. In reality, during construction any discrete fractures that yield excess water will be grouted which will reduce the actual overall tunnel inflow volume and groundwater drawdown. Therefore, the inflow (and subsequent impacts) would be less than predicted due to mitigation and management measures undertaken during construction (such as pre-grouting and segmental lining).

Two models were developed. A groundwater model that predicted overall percentage reduction in baseflow at a catchment scale (**Figure 6-2**) and a catchment model that allowed more detailed modelling to be undertaken at individual sub-catchment scale sites (**Figure 6-3**).

Where the groundwater model predicted a great than 2% reduction in baseflow, the catchment model was used to predict more detailed flow exceedance probability curves and determine the predicted changes to categories of flow, particularly increases in 'no flow' (i.e. flow ≤ 1 ML/day / approx. 10 L/s). Given limitations of the modelling, however, differentiation between true no flows (i.e. 0 ML/day) and flows > 0 ML/day and up to 1 ML/day (i.e. no flow as defined here) cannot be made. This hinders the assessment of impacts to aquatic ecology as true no flows would be expected to cause greater impacts compared with flowing water up to 1 ML/day. Hydrographs displaying unimpeached and impacted flow for the period December 2007 to 2012 were also produced to help visualise changes in flow that could occur during typical years.

The catchment model provided predictions relevant to a number of selected sites on watercourses in catchments of the Yarrangobilly, Eucumbene and Upper Murrumbidgee rivers:

> Gooandra Creek: Site 3 (Upper Murrumbidgee catchment);

> Tantangara Creek: Sites 5 and 6 (Upper Murrumbidgee catchment);

> Eucumbene River: Sites 2, 9, 10 and 11 (Eucumbene catchment);

> Murrumbidgee River: Murrumbidgee Gauge (Upper Murrumbidgee catchment);

> Yarrangobilly River: Yarrangobilly Gauge (Yarrangobilly catchment); and

> Wallaces Creek: Wallaces Gauge Yarrangobilly catchment.

Importantly, predictions from the catchment model are directly applicable only to the watercourse at these selected sites. For sections of watercourses upstream and downstream of sites, changes in flow have been inferred from predicted wider scale groundwater drawdown and site-specific changes at individual sites, themselves based on a number of assumptions, including sub-catchment rainfall, hydraulic connectivity of the rock, and groundwater flow paths, all of which may influence changes in water availability that do occur.

Tunnel inflows are predicted to peak in the final year of construction. Changes in baseflow are predicted to develop more slowly, with maximum reduction occurring several decades after the completion of construction (**Figure 6-4**) (EMM 2019a – Appendix J). Predicted changes in baseflow at each catchment range between 0.60 % and 30.60 % (**Table 6-8**). Very small reductions in baseflow are unlikely to result in a measurable reduction in stream flow, and, as such, changes in Middle Creek, Yarrangobilly River, Wallaces Creek, most of the upper Murrumbidgee River, most of Tantangara Creek (including the stocky galaxias population) and Nungar Creek do not require further consideration (EMM 2019a – Appendix J). Modelling of baseflow reductions was insteadfocused on Gooandra Creek (Site 3), Tantangara Creek (Sites 5 and 6 only), Murrumbidgee River (Murrumbidgee River Gauge only), Eucumbene River (Sites 2, 9, 10 and 11) and Stable Creek (using the Yarrangobilly River and Wallaces Creek gauges).

Reduction in surface flow volumes in watercourses in the Upper Murrumbidgee River Catchment would be greatest in Gooandra Creek. In particular, there would be an increase in the number of no flow days (i.e. flow ≤ 1 mL/d) at Site 3 on Gooandra Creek (just upstream of its confluence with Tantangara Creek). Periods of no flow at Site 3 are predicted by the modelling to increase from 3 % to 17 % overall and from 4 % to 23 % in summer. In summary, based on drawdown contours, increases in the number of no flow days would be expected to be more noticeable further upstream of Site 3 in Gooandra Creek, and would peak where the creek intersects the tunnel alignment at the location of greatest groundwater drawdown. Comparison of predictive drawdown at Site 3 and further upstream suggests that approximately 2 km to 3 km of the main channel of Gooandra Creek could be affected by an increase in the number of no flows days in excess of that predicted at Site 3. Several kilometres total length of associated first and second order tributaries would likely also experience similar increases in the number of no flow days.

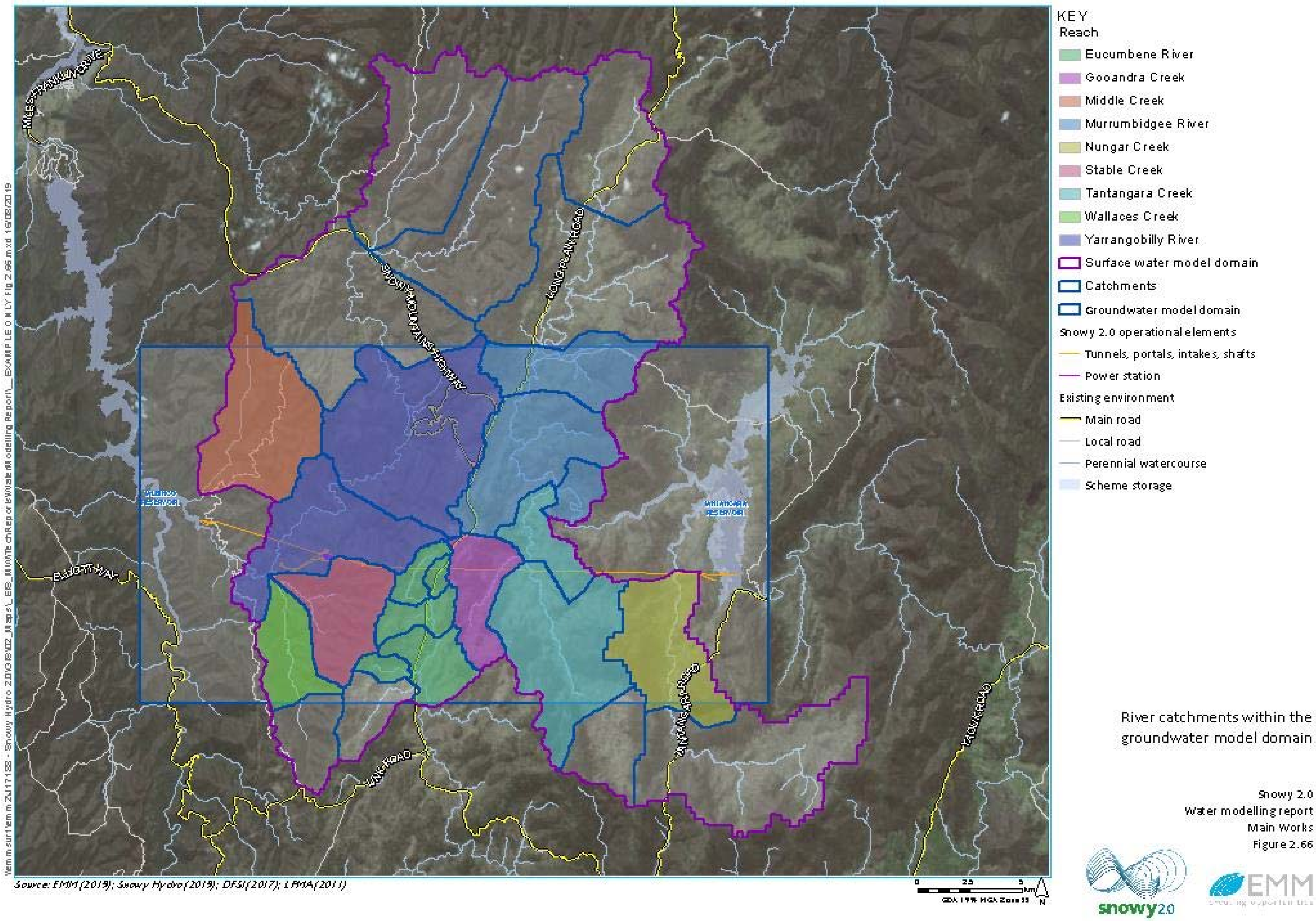

Figure 6-2 Catchments (colour shaded areas) within the groundwater model

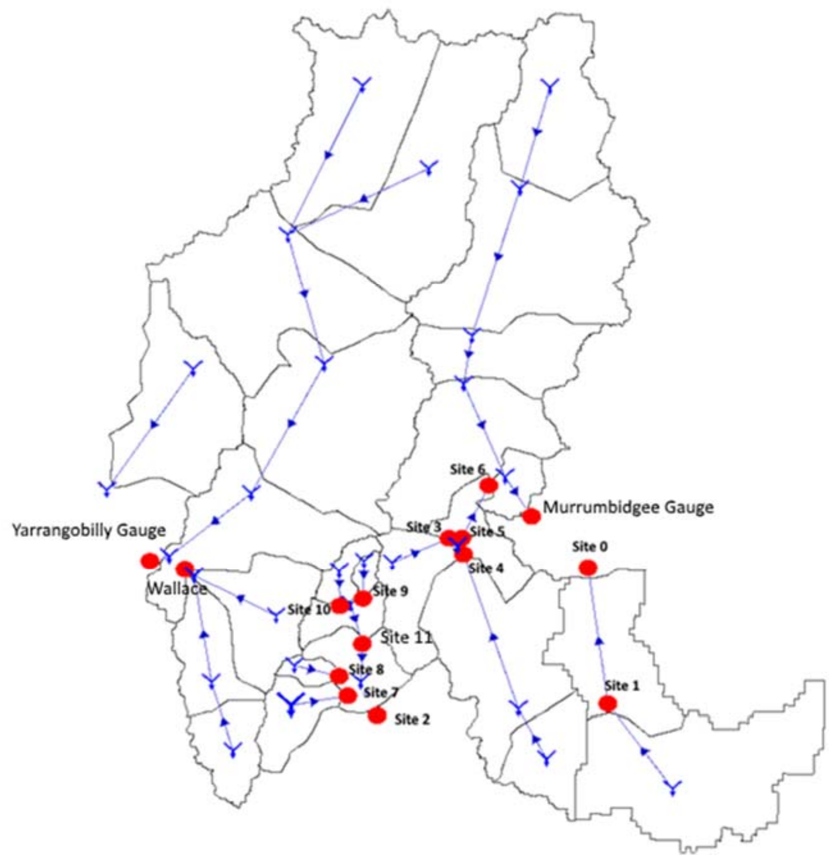

Figure 6-3 Location of catchment model reporting sites

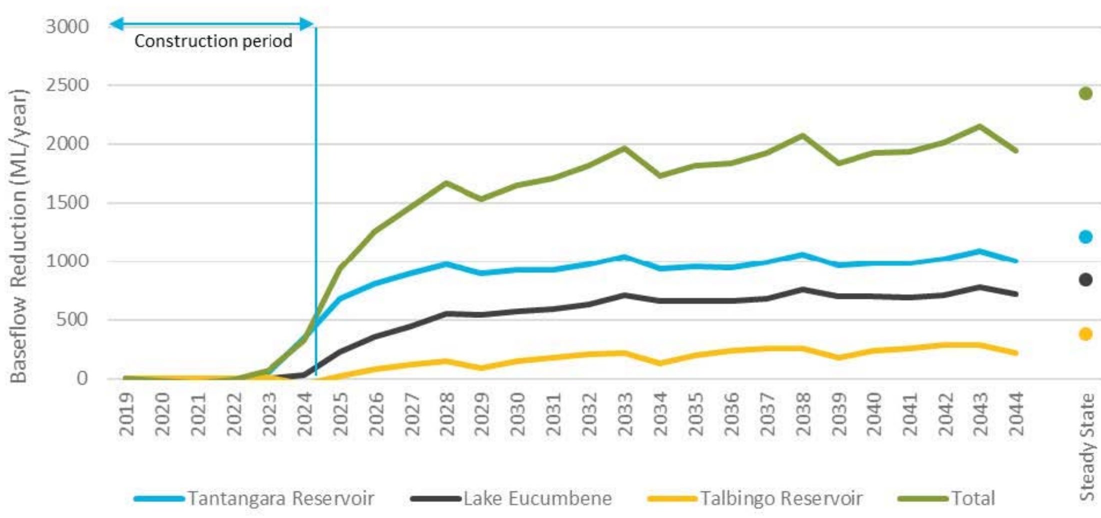

Figure 6-4 Baseflow reduction predicted by the groundwater model within each reservoir catchment (source: EMM 2019A – Appendix J).

Table 6-8 Predicted baseflow reductions for catchments within the groundwater model.

	Middle Creek	Yarrangobilly River	Wallaces Creek	Stable Creek	Eucumbene River	Murrumbidgee River U/S of gauge	Tantangara Creek	Gooandra Creek	Nungar Creek
Reduction in Baseflow (%)	0.10	1.60	1.20	6.70	19.50	0.02	0.60	30.60	0.30

The modelling indicates that substantial reductions in flow in the Upper Murrumbidgee River Catchment would be restricted largely the Gooandra Catchment, with no increase predicted in the number of no flow days at Site 5 on Tantangara Creek just downstream of the confluence with Gooandra Creek. Only a small increase in the number of low flow days (between 2 % to 4 % increase) is predicted at this site. Similarly, there would be no increase in the number of zero flow days in the Murrumbidgee River at the Murrumbidgee River Gauge and only 1 % increase in the number of low flow days. The greater flows in Tantangara Creek and Murrumbidgee River, combined with being located largely outside of the predicted drawdown extent would appear to explain the relatively minimal changes in flow predicted for these watercourses.

Modelling also indicated that flow in some first and second order tributaries of Nungar Creek, Kelly's Plain Creek and Tantangara Reservoir between Nungar Creek and Tantangara Reservoir would be affected by drawdown, with a potential increase in the number of no flow days in these watercourses. Based on the size of the catchments these watercourses are likely to be naturally ephemeral or intermittent, and only a relatively small (0.3 %) reduction in baseflow is predicted for Nungar Creek. Localised drawdown would also occur adjacent to several other first and second order tributaries of Tantangara Creek and Murrumbidgee River. This could result in localised increases in the number of no flow days in these watercourses, although this is not expected to result in noticeable changes in flow in the main channels of either Tantangara Creek or Upper Murrumbidgee River.

Conservative model predictions for the the Eucumbene River adjacent to the tunnel alignment indicate possible periods of no flow are predicted overall to increase from 14 % to 26 % (Site 10), 33 % to 39 % (Site 9), 3 % to 17 % (Site 11) and from 0 % to 3 % (Site 2). Increased no flow days could be greater during summer at Sites 10 (21 % to 40 %) and 11 (4 % to 23 %). Based on drawdown contours, greater reductions in flow in Eucumbene River are predicted upstream of these sites adjacent to the tunnel alignment, where groundwater levels could reduce by around 20 m. In comparison, Sites 2, 9, 10 and 11 on the Eucumbene River are predicted to have < 2 m drawdown. Reduced flow in the Eucumbene River could occur from its headwaters to around Site 2 (approximately 12 km length of watercourse), being most pronounced further upstream.

Compared with the Upper Murrumbidgee River Catchment, where drawdown is relatively uniform, drawdown in the Yarrangobilly River catchment (e.g. Stable Creek) would be more localised. Although very minimal changes in baseflow are predicted overall for Yarrangobilly River and Wallaces Creek, and no changes in flow exceedance curves at either the Wallaces Creek or Yarrangobilly River gauges, reduced flow could be more noticeable in their upstream tributaries. A 6.7 % reduction in baseflow to Stable Creek (a tributary of Wallaces Creek) is predicted, although no modelled sites are on or near this tributary. It is possible that Stable Creek, and several other first, second and greater order tributaries of Wallaces Creek and Yarrangobilly River, could experience an increase in the number of no flow days. Based on flow exceedance curves for the Wallaces Creek and Yarrangobilly River gauges, reductions are likely to be restricted to the upper catchment.

6.5.2 Impacts on Aquatic Habitat and Biota

6.5.2.1 Upper Murrumbidgee River Catchment

The increase in the number of no flow days predicted in Gooandra Creek and its tributaries could result in an overall reduction in availability of aquatic habitat in these watercourses. This section of watercourse is relatively narrow (approximately 1 m wide), though contains large rocks, native in-stream aquatic plants, pools and small riffle sections with a variety of stream substrata (sand, gravel, pebble, cobble and some bedrock) and is classified as type 1 KFH. Reductions in the availability of these habitats during low flows and if flows were to cease would be associated with an overall reduction in the population sizes of associated aquatic biota in this catchment and potential mortality in any reaches that dry out. Relatively mobile aquatic fauna occurring in these watercourses, such as salmonids and Reik's crayfish, may be able to relocate to areas unaffected by water level reductions. It is possible that some individuals would be lost if they became stranded in disconnected sections of the watercourse. Predicted reductions in availability of aquatic habitat are expected to be be most noticeable during late summer periods of reduced rainfall. Flow reductions and drying of watercourse channels could ocur in shallower riffle sections, where less mobile biota (small macroinvertebrates and instream aquatic plants) could be affected. In the case of Reik's crayfish, impacts to this species may be limited as it is able to survive out of water for periods longer than fish. This could provide a greater ability to migrate overland to pools unaffected by reductions in water levels.

Although reductions in flow in Gooandra Creek could result in relatively severe impacts to aquatic biota (mainly macroinvertebrates), such impacts would be largely localised to this catchment, and are not expected to extend to the wider Tantangara Creek and Upper Murrumbidgee River Catchments. In comparison, with the entire length of watercourses in each catchment, only small sections are predicted by modelling to experience reduced flow as a result of groundwater drawdown.

In addition to potential impacts to aquatic habitat within the drawdown reach of Gooandra Creek, any loss of flow could affect reaches uipstream of the drawdown through loss of connectivity with the rest of the catchment. If this occurred, biota would be unable move up- or downstream of the drawdown reach until flows returned to the drawdown sections (e.g. following sufficient rainfall).

No native species of fish and, aside from Reik's crayfish, have been identified from the section of Gooandra Creek adjacent to the tunnel alignment during the extensive field surveys undertaken here (**Annexure B**). Aquatic fauna and flora present in Gooandra Creek are abundant throughout the Upper Murrumbidgee River Catchment. Brown trout and rainbow trout are also present in these watercourses and may lose access to the drawdown reach or further upstream if they use theses reaches for spawning or nursery habitat, the relatively small size of riffles in Gooandra Creek and other tributaries are unlikely to provide important spawning habitat for salmonids. Gooandra Creek appears to experience periods of no flow naturally, with local aquatic assemblages adapted to periods of no flow and therefore able to tolerate increases due to predicted drawdown. At the scale of the Upper Murrumbidgee River Catchment, impacts to aquatic habitat and biota that would occur in Gooandra Creek and in other tributaries due to localised drawdown would be relatively minor. A reduction in longitudinal connectivity is also possible in Gooandra Creek and in other nearby tributaries of Tantangara Creek and Murrumbidgee River. This could impact the ability of aquatic fauna to move between different sections of watercourses in search of food, refuge and potentially their ability to access habitats related to reproduction (such as riffle sections or aquatic plants). Reductions in connectivity would therefore also be expected to result in some reduction in the local population size of aquatic biota. Any effects of reduced connectivity would be temporary and persist until flow returned following rainfall events. Such impacts would be restricted to sections of Gooandra Creek and other tributaries and would be relatively minor in the context of the wider Upper Murrumbidgee River Catchment.

Similarly, any changes in water quality that could occur in pools, limiting the spatial extent of possible impacts to aquatic biota. Altered water quality would be temporary and persist only until flow returned to the watercourse following rainfall events. When they occur, flood events would also mobilise and transport sediments that may have accumulated during low flow periods. Sediments could be washed downstream to watercourses unaffected by reduced surface flows. Any habitat modification that could result from sediment deposition during low flows would likely be temporary and flushed downstream during rainfall or snow melt.

6.5.2.2 Lake Eucumbene Catchment

The expected increase in number of no flow days in the Eucumbene River and its tributaries could result in an overall reduction in the availability of aquatic habitat in the river and its tributaries. Approximately 10 km of the main channel of Eucumbene River (from its headwaters to Site 2) could experience some reduction in habitat availability due to reduced flows. Habitat loss would be greatest within the upper 2 to 4 km of its headwaters that intersects the tunnel alignment. Given the substantial groundwater drawdown that could occur here, and the relatively small catchment area, habitat loss within this reach could be substantial. The aquatic habitat within this section is relatively limited, consisting primarily of a narrow channel 0.5 to 1 m wide, with some shallow pools connected by shallow flowing water over pebble and gravel substratum. Rainbow trout and Reik's crayfish were caught in this section of river, although no native aquatic plants were recorded. Reduction in the availability of aquatic habitat is also predicted to occur further downstream to Site 2; although it would be relatively minor by the time the watercourse reaches Site 2 (an increase in no flows of only 0 % to 3 % is predicted at Site 2). This section of the river provides some more substantial aquatic habitat, including wider channels over 1 m wide, deeper pools and native aquatic plants. As is the case for the Upper Murrumbidgee River Catchment, the extent of associated impacts to aquatic habitat and biota in this section of Eucumbene River (and its associated tributaries) would be minor in the context of the Lake Eucumbene Catchment.

6.5.2.3 *Yarrangobilly River Catchment*

Reduction in groundwater levels in the upper sections of Yarrangobilly River and Wallaces Creek could result in localised reductions in stream flow and availability of aquatic habitat. Where low or no flow occurs, there could be reduced connectivity between pools and reaches of these watercourses. Baseflow reductions are predicted to be greatest, though relatively minimal, in the Stable Creek Catchment. At its confluence with Wallaces Creek, these two watercourses are indistinguishable, and contain unconsolidated boulder, cobble, pebble and gravel substrata with little evidence of siltation (**Annexure B**). There could be some reduction in the availability of aquatic habitat and reductions in habitat connectivity in approximately 6 km of Yarrangobilly River and 4 km of Stable Creek and in other tributaries of the Yarrangobilly River Catchment. These changes could affect a relatively minor component of the entire Yarrangobilly River Catchment. Predicted drawdown is also relatively localised in these areas, which would limit reduction in flows that might otherwise occur there. Such affects would be restricted to upstream reaches, and no reduction in flow is predicted for downstream at the Yarrangobilly and Wallaces gauges.

6.5.2.4 *Impacts on KFH, Threatened Species and EECs*

Third and higher order sections of Gooandra Creek, Eucumbene River and Stable Creek provide Type 1 – Highly Sensitive KFH. The conservatively predicted drawdown of groundwater levels and reductions in flow in these watercourses could result in the reduced availability of KFH in approximately 5.5 km, 10 km and 11 km of watercourses in the Gooandra Creek, Eucumbene River and Yarrangobilly River catchments, respectively. Given the abundance of such habitat in each of these catchments, associated impacts to fish and crayfish would like be relatively minor.

Murray crayfish occurs in Yarrangobilly River and Wallaces Creek, and is also likely to occur in Stable Creek. It is possible that this species may be affected by reduced habitat availability and habitat connectivity in these watercourses. However, given the abundance of comparable habitat throughout the Yarrangobilly River Catchment, and the localised potential effects on flow availability due to drawdown, any impacts to Murray crayfish do not represent a risk to the population of this species.

The section of the Eucumbene River predicted to experience reductions in flow is part of the Snowy River EEC. This could result in impacts to this EEC and associated species. In the context of the wider EEC, such impacts would occur in a relatively small extent of its total area. The most severe predicted reductions in flow would also occur in the upper headwaters of the Eucumbene River, which provides relatively limited aquatic habitat compared with the much larger sections of the Eucumbene River further downstream.

6.5.3 Mitigation Measures and Residual Risks

During tunnel construction, any discrete fractures that yield excess water would be grouted to reduce the actual overall tunnel inflow volume. Groundwater inflow (and subsequent impacts) would therefore be minimised due to mitigation and management measures committed to during construction (i.e. pre-grouting and segmental lining). The residual risk of tunnel excavation and groundwater drawdown activities on sensitive receptors is in **Table 6-9**.

Table 6-9 Qualitative risk assessment of likelihood and consequences of tunnel excavation before and after proposed mitigation. L=Likelihood of occurrence; C = Consequence of occurrence. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Reduction in the availability and connectivity of aquatic habitat	Upper Murrumbidgee River Catchment	Threatened species	N/A	N/A	N/A	N/A	N/A	N/A
		Native species	Possible	Moderate	Moderate	Possible	Moderate	Moderate
		Salmonids	Possible	Moderate	N/A	Possible	Moderate	N/A
	Lake Eucumbene Catchment	Native species	Possible	Moderate	Moderate	Possible	Moderate	Moderate
		Salmonids	Possible	Moderate	N/A	Possible	Moderate	N/A
		Snowy River EEC	Possible	Moderate	Moderate	Possible	Moderate	Moderate
	Yarrangobilly River Catchment	Native species	Possible	Moderate	Moderate	Possible	Moderate	Moderate

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
		Salmonids	Possible	Moderate	N/A	Possible	Moderate	N/A
		Threatened species – Murray crayfish	Possible	Moderate	Moderate	Possible	Moderate	Moderate

7 Assessment of Operational Impacts

7.1 Overview

Aspects of Snowy 2.0 operational activities with potential to affect aquatic ecology include:

> Transfer of water between Talbingo Reservoir and Tantangara Reservoir;
  - Changes to physical and chemical characteristics of water within each reservoir;
  - Entrainment of biological material;
  - Transfer of fish between reservoirs;
  - Transfer of phytoplankton between reservoirs; and
  - Transfer of diseases between reservoirs.
> Maintenance or decommissioning of infrastructure and utilities;
> Ongoing groundwater drawdown;
> Dewatering of the headrace and tailrace tunnel and station drainage; and
> Cumulative impacts

7.2 Transfer of water between Talbingo Reservoir and Tantangara Reservoir

During the commissioning and operational phase of Snowy 2.0 water transfers between Talbingo Reservoir and Tantangara Reservoir would occur. This would provide on-demand electricity generation and pumping which will provide energy storage capacity and stability to the national energy grid.

7.2.1 Changes to physical and chemical characteristics of water within each reservoir

7.2.1.1 Description of Impacting Processes

Operation of Snowy 2.0 has potential to cause changes in water quality in Talbingo Reservoir, Tantangara Reservoir and their downstream catchments (Chapter 6 in the Snowy 2.0 Main Works EIS). These could occur due to the following:

> Changes in physical and chemical characteristics of water in each reservoir due to transfer and mixing of water between Talbingo Reservoir and Tantangara reservoirs;
> Mobilisation of reservoir bed sediment in Talbingo Reservoir and Tantangara Reservoir during power generation and pumping. This would occur due to scouring of the substratum due to elevated flows in the vicinity do the intakes; and
> Transport of suspended sediment (from excavated material and/or reservoir bed sediments mobilised during power generation and pumping) downstream of Talbingo Reservoir to the Tumut River Catchment and downstream of Tantangara Reservoir to the Mid Murrumbidgee River Catchment and Lake Eucumbene Catchment.

Changes in Water Quality due to Transfer and Mixing of Water

Over the long-term (years to decades), the primary impact on water quality in the reservoirs is expected to be changes due to the mixing of the water between the reservoirs. These changes may not be deleterious but will likely result in an equilibrium being established in both reservoirs. Changes may be most noticeable in Tantangara Reservoir due to the greater exchange of water relative to its volume.

While it is desirable to predict these changes, this is not possible due to uncertainties surrounding the water transfer regime, which would depend, among other factors, on fluctuations in the national energy market. However, some general predictions may be made regarding potential changes to water quality from the mixing of water between the reservoirs during operation. As active storage in Tantangara Reservoir is approximately 93.9 % of the gross storage (i.e. the maximum volume of water that may be transferred between the reservoirs), the potential for water temperature change is higher in Tantangara Reservoir than in Talbingo Reservoir where active storage is approximately 17.3 % of the gross storage. Importantly, based on 2018 to 2019 water quality monitoring and default guideline values, mixing of the reservoir waters during operations is unlikely to significantly impact pH, EC, turbidity, DO (except as a result of temperature changes), nutrients and concentrations of metals. Two possible exceptions are aluminium and copper, the concentrations of which (on a few occasions) suggested levels may differ between the reservoirs. Based on available information, associated impacts to aquatic flora and fauna in the reservoir are unlikely to be significant.

Mobilisation of Sediments in Reservoirs and Transport Downstream

Resuspension of settled placement sediment and mobilisation of reservoir bed sediments in Talbingo Reservoir and the transfer of sediment mobilised in Tantangara Reservoir, could result in impacts to aquatic habitat and biota comparable to those described in **Section 6.3**. The mobilisation of reservoir bed sediments in Tantangara Reservoir, and the transfer to of sediment mobilised in Talbingo Reservoir, could also result in impacts to aquatic habitat and biota in Tantangara Reservoir comparable to those described for Talbingo Reservoir in **Section 6.3** (albeit with potentially lower consequences due to different receptor species). The potential transport of mobilised sediments to catchments downstream of each reservoir could also affect aquatic habitat and biota here. The design of the intake channels and the measures set out in the WMP and Commissioning plan would ensure that the potential for sediment mobilisation in the reservoirs and downstream transport of harmful volumes of sediment out of the reservoirs during commissioning and operation is minimised to the greatest extent practicable. In the unlikely event that the release of potentially harmful amounts of sediment cannot be avoided, DPI Fisheries would be consulted to ensure that appropriate measures can be put into place to minimise impacts to sensitive aquatic receptors.

7.2.2 Entrainment of biological material

7.2.2.1 Description of Impacting Processes

The proposed Snowy 2.0 intake/outlet structure at Talbingo Reservoir would be located in the Yarrangobilly River arm of Talbingo Reservoir. The structure is currently assumed to have a bell mouth opening consisting of four smaller openings of 10 m high by 4.75 m wide covered with trashracks with bar spacings not exceeding 120 mm, corresponding to an approximate gross surface area of 190 m^2. Once constructed, the top of the intake would be 9–18 m below the surface of Talbingo Reservoir depending on the reservoir level. An approach channel would be constructed in front of the Talbingo intake to enable the smooth intake and exit of water during operation. All potential fish habitat such as timber or rocky outcrops would be expected to be removed during construction. Water velocity through the Talbingo intake would not exceed 2 m/s during full station pumping (i.e. when all pumps are in operation) and would reduce if fewer pumps are operating.

In pumping mode, the maximum flow at the inlet would be approximately 260 KL/s (0.936 GL/hr) transferring water from the Yarrangobilly River arm of Talbingo Reservoir to Tantangara Reservoir. Potential entrainment impacts below have been determined based on this maximum flow.

The proposed intake/outlet structure at Tantangara Reservoir would be located at the southern end of the reservoir on the western side approximately 1 km upstream of the dam wall. The intake/outlet structure is currently assumed to comprise a bell mouth opening of approximately 31.5 m wide by 17.25 m tall, corresponding to an opening area of 427 m^2. The top of the intake would be located slightly below the natural bed level of reservoir and approximately 12 m below the 2011 to 2018 median lake water level. The base of the intake would be below the current base of the reservoir. In power generation mode the maximum flow at the inlet would be approximatley 400 KL/s transferring water from Tantangara Reservoir to the Yarrangobilly River arm of Talbingo Reservoir. Entrainment risk below has been determined based on this maximum flow.

During operation, the intakes at both reservoirs would have potential to directly impact upon aquatic flora and fauna within the reservoir via entrainment into the intake. The potential direct impacts of entrainment on flora and fauna are described as follows:

- Hydraulic entrainment of biota – the process of biota being drawn into the intake because they are unable to avoid the ingoing stream of water. This could occur in Talbingo Reservoir during pumping and in Tantangara Reservoir during electricity generation mode. Large and small biota may be entrained within the intake stream. This has the potential to result in:
  - Transfer to Tantangara/Talbingo Reservoir (see **Section 7.2.3**, **Section 7.2.4** and **Section 7.2.5**); or
  - Mortality - Once entrained, biota passing through hydroelectric turbines could be injured or killed due to rapid and extreme pressure changes, cavitation, blade strike, grinding, turbulence, and/or shear stress (Čada et al. 2007, Ning et al. 2019). The extent of the injuries and the mortality rate depend on the level of these stressors but also on species, body length and, in the case of pumping stations, potentially on pump type (Buysse et al., 2014) and mortality can vary between 0 and 100% (Bierschenk et al., 2019). It is known that different species and biota of different sizes have different

susceptibilities to pressure changes or shear stress (Trumbo et a. 2014, Ning et al. 2019) whereas the risk of collisions increases with larger size (Gloss & Wahl, 1983); and

> Impingement of entrained biota – this process could occur if biota that had been drawn into the intake are caught on screens fitted to the mouth or tunnel of the intake. Generally, impingement relates to larger fish and larger mobile invertebrates. Based on the proposed rack dimensions, (relative to the size of fish likely to be in the reservoirs, the likelihood of impingement is considered to be rare and this process has not been assessed further.

Characteristics of the intake structures (including the size of the mouth and positioning of the intake structure, the operation times, durations, speed and direction of the intake stream) as well as characteristics of the affected organisms (including size, buoyancy, mobility, seasonal availability of potentially vulnerable life-history stages and habitat preferences) affect the potential for entrainment (Ning et al. 2019).

Given that the ability of biota to escape or avoid entrainment typically relates to the magnitude of velocities generated near the intake (approach velocity), particularly perpendicular to it (Swanson, et al., 2004), the surface area of the Snowy 2.0 transfer intakes have been purposely designed to be large to minimise water velocities within the vicinity of the mouth of the intake structure.

Some life-history stages of fauna in the reservoirs may be able to swim fast enough to escape entrainment into the intake stream, others such as eggs and newly hatched larvae may not. Entrainment of some of the life history stages of a species would result in at least transfer out of the reservoir, if not mortality. Depending on the number of individuals affected relative to the abundance of the life-history stage of the species in the reservoirs, this could affect populations within each reservoir.

For this impact assessment available information was reviewed on the distribution, abundance, behaviour, habitat, size and swimming speeds of the various life-history stages of species known or potentially occurring in the reservoirs. This information was used to determine vulnerabilities to entrainment that could cause significant changes to abundance to populations ‘within the source reservoir only’. This was done for all trophic levels.

7.2.2.2 Talbingo Reservoir

Direct Impacts – Entrainment of biological material

1. Phytoplankton and zooplankton

The phytoplankton communities of Talbingo Reservoir are described in **Section 5.3.7**. By definition, planktonic organisms are passively advected and spatially distributed by current velocities that exceed their own swimming capabilities. Phytoplankton (even those with flagella) have virtually no ability to swim against currents. For zooplankton occurring in lakes, which are most abundant in size classes ≤ 1 mm, swimming speed can be estimated to be in the order of a few body lengths per second (Huntley & Zhou, 2004), or generally < 1 cm/s (~ 0.01 m/s). Hence, in horizontal dimensions, with typical current velocities in the reservoirs of generally less than several centimetres per second, zooplankton, like phytoplankton, can also be considered passive drifters (Huber, et al., 2011). In the vertical dimension, however, where current velocities are generally less than horizontal speeds, some species of phytoplankton and zooplankton can perform purposive movements, e.g. diel vertical migration (DVM) e.g. Cohen & Forward (2009).

In lakes and reservoirs, phytoplankton groups generally show differential vertical distributions as they optimise conditions for growth (i.e. in relation light and nutrient availability) according to their specific physiologies and motilities. Given there is no available information on depth distribution of plankton in Talbingo Reservoir the following risk appraisal (of entrainment) has been made with reference to generalities in the literature for lake plankton and physical and chemical attributes of Talbingo Reservoir.

Peak biomass of different phytoplankton groups may be expected at different depths: diatoms near the metalimnion (i.e. the area around the thermocline) where colder, denser water can prevent their sinking. Some cyanophytes which can modulate their position by buoyancy might form surface blooms, whereas cryptophytes may peak in the metalimnion where their low-light and high-nutrient requirements are normally satisfied (reviewed by Longhi & Beisner, 2009). However, in Talbingo Reservoir, where the thermocline is generally at a depth of about 10 m (apart from winter) and where water clarity restricts the photic zone to within a few metres of the surface, it is expected that this is not the case, and that bulk phytoplankton biomass is within the surface layers (i.e. within the top few metres within the photic zone). Given the top of the intake would be at 9-18 m below the surface depending on the level of the reservoir it is likely that most phytoplankton biomass would be above the water layers most affected by the intake stream, particularly when the reservoir level is high.

The potential for entrainment of zooplankton would be greater than for phytoplankton given its potential to occupy deeper water, at least for part of the day. For zooplankton in lakes, the vertical distribution is the result of active habitat choice. DVM occurs as a daily habitat shift in response to changing suitability. Large zooplankters generally leave the warm, lighted and often food-rich epilimnion (surface areas above the thermocline) during the day to dwell in the cold, dark hypolimnion (below the thermocline) where food may be of low quantity and poor quality, in order to avoid predation. They return to the surface layers at night when the predation risk is small (reviewed by Lampert, 2005). Again, given the Spring, Summer and Autumn thermocline in Talbingo Reservoir sits at about 10 - 15 m below the surface, it is not clear if the DVM of zooplankton would extend to the hypolimnion. Notwithstanding this, given DVM of zooplankton would be expected to some depth below the surface, some portion of the vertical extent of the bulk of zooplankton during the day would probably be within the water layers potentially affected by the intake stream.

Given the maximum velocities expected to occur at the mouth of the Talbingo Reservoir intake, plankton within the vicinity of the intake, and within the depth range of the intake stream, would be vulnerable to entrainment. The available evidence from other field-based studies has shown that zooplankton concentrations near intake structures are similarto those outside the influence of the intake and there is no evidence to suggest that concentrations of plankton would be particularly greater at the parts of the reservoirs where the intakes were located compared to other areas. Notwithstanding this, it is expected that some plankton would be entrained.

Importantly, given the large volume of the reservoir the likely average daily abstractions would be a small fraction of the total volume of reservoir water. Thus, the relative proportion of total plankton with the potential to be entrained is low. Given the large natural variability in plankton concentrations observed within the reservoirs, it is likely that any impacts would not be detectable (i.e. insignificant). This risk is also similar to the existing risk of entrainment into the Tumut 3 power station. In addition, some portion of plankton entrained and transferred to Tantangara Reservoir may be returned during the generation phase. As a result, the overall risk of entrainment to plankton is 'low'.

2. Fish and invertebrates

a) Eggs

Fish occurring in Talbingo Reservoir include a mixture of native and introduced species although introduced species make up a large proportion of the fish community (**Section 5.3.5**). Given most species of these species lay adhesive eggs to submerged objects such as vegetation and rocks (typically at depths shallower that the proposed depth of the intake (Ning et al. 2019), and in the case of trout, migrate up tributaries to spawn their eggs (**Table 7-1**), the likelihood of fish eggs being entrained is 'rare'. The risk is further reduced given the intake area would be cleared of typical spawning substrata such as timber and macrophytes. Eggs of the freshwater crayfish (Family Parastacidae) in the reservoir, including the threatened Murray crayfish, would also not be at risk given females carry eggs on pleopods until they hatch in summer.

Some soft sediment macroinvertebrates are the only biota occurring or potentially occurring in Talbingo Reservoir that spawn pelagic or semi buoyant eggs (**Table 7-1**), which would drift with water flow and hence would have potential for entrainment. As these eggs have a high turnover and the number affected would be a very small relative to the total reservoir volume, the impact on these and eggs in general, is expected to be insignificant and the risk is therefore considered to be low.

This conclusion is supported by research at an existing Pumped Hydro-electric station, Northfield mountain, which found that even for fish species that produce pelagic eggs, the total proportion of eggs and larvae entrained into a pumped hydro station is low compared to the estimated total population in the source reservoir (Kleinschmidt, 2016).

Table 7-1 Egg laying method and reproductive season of species with a likelihood of occurance of moderate or above within Talbingo Reservoir or its tributaries.

Major Group/Scientific Name	Common Name	Egg Laying Method	Reproductive Season
Phytoplankton	-	n/a	Mainly warmer months
Zooplankton	-	Pelagic	Mainly warmer months
Macroinvertebrates			
Soft sediment benthos	Various taxa	Variable, but includes some taxa with pelagic eggs	Variable
Cherax sp.	Common yabby	Carried by female	Spring / summer

Major Group/Scientific Name	Common Name	Egg Laying Method	Reproductive Season
Euastacus armatus	Murray crayfish	Carried by female	Autumn / winter
Paratya australiensis	Freshwater glass shrimp	Carried by female	Winter / spring
Fish (Native)			
Galaxias brevipinnis	Climbing galaxias	Demersal adhesive	Autumn / winter
Galaxias olidus	Mountain galaxias	Demersal adhesive	Spring / summer
Gadopsis bispinosus	Two-spined blackfish	Demersal adhesive	Spring / summer
Maccullochella macquariensis	Trout cod	Adhesive	Spring
Philypnodon grandiceps	Flathead gudgeon	Adhesive	Spring / summer
Fish (Non-Native)			
Gambusia holbrooki	Eastern gambusia	Live bearers	Spring
Carassius auratus	Wild goldfish	Adhesive	Spring
Salmo trutta	Brown trout	Demersal (sinking)	Spring
Oncorhynchus mykiss	Rainbow trout	Demersal (sinking)	Spring
Perca fluviatillis	Redfin perch	Adhesive	Spring / summer

b) Larvae

After hatching from eggs, most bony fish continue life as a larva, a few millimetres in length. Larvae have to swim effectively almost immediately after hatching to hunt prey to gather resources for their growth and development, disperse, and escape from predators. Bony fish larvae change shape considerably over development. When the larvae hatch, they have an elongated body surrounded by a continuous finfold behind the head and yolk sac. As the larvae grow and develop into juveniles, the body shapes of the different species diverge to prepare them for their adult lifestyle and swimming styles (reviewed by Voesenek, et al., 2018). With growth, inertia becomes more important during swimming and larvae become faster swimmers e.g. Kopf, et al., (2014). The associated relative drag reduction allows many fish to shift towards a carangiform swimming mode by reducing the relative curvature amplitude along their bodies. There are generally two types of swim modes: cruise (for larvae maintaining position in habitats or dispersing to other areas) and fast-start performance (to hunt or escape predators). Larvae can maintain the first mode for much longer than the second.

Freshwater crayfish do not have a larval stage. Rather, juveniles emerge from the egg stage.

Kopf et al. (2014) investigated critical (<30 min) and prolonged or sustained (>60 min) swimming speeds in laboratory chambers for larvae of six species of Australian freshwater fishes, of which one species, trout cod, occurs in Talbingo Reservoir. The developmental stage generally better explained swimming ability than did length, size or age (days after hatch) so that well-developed larvae could swim up to 10 times faster than newly hatched larvae. Trout cod larvae had the highest prolonged swimming speeds (maximum ranging between 0.06 m/s and 0.15 m/s among larval stages of species investigated which is significantly lower than the maximum predicted velocity of 2 m/s at the intake.

Little is known of the depth preferences of the larval stages of various species within the reservoir, although Ning et al. (2019) observed that the redfin perch larvae in their study were positively buoyant (floating) up until six day's post-hatch and hence would be close to the surface at this time, with reduced risk of entrainment would be a risk (Ning et al. 2019). Nevertheless, the study concluded that it was likely some redfin perch larvae could be found at a depth equivalent to the proposed intake and thus be at risk of entrainment. In the absence of other data, the same is concluded for other species within the reservoir, with the exception of easterngambusia which are known to typically inhabit very shallow habitat (often 15-20 cm) (Pyke, 2005).

It is considered 'likely' that some fish larvae within the immediate area in front of the intake could potentially be entrained, although the bulk of these would likely be introduced species. As Trout Cod are stocked into the reservoir as juveniles, and there is no evidence of breeding within the reservoir, the likelihood of entrainment of larvae of this species is 'rare'. As for plankton, given the large volume of Talbingo Reservoir, the potential daily abstractions would be a small fraction of the total volume of reservoir water so the relative proportion of total larvae with the potential to be entrained is low and consequently 'insignificant' leading to a low risk of impact.

c) Juvenile and adults

As indicated above, the top of the intake in Talbingo is expected to be 9–18 m below the water surface, depending on reservoir level, and the base a further 10m below that. Although the intake stream would be strongest perpendicular to the mouth it would also draw water to its sides albeit at reduced water velocities. Juveniles and adults of the native and non-native species known to occur in Talbingo Reservoir are typically found in littoral habitat or in the top layers of the water column rather than the very deep waters of the reservoir. Although the depth of the intake would be outside the area considered to be preferred habitat some areas of occupancy of all species in the reservoir would potentially overlap with the upper areas of the intake stream (particularly when the reservoir was operating at or close to MOL), so that some juveniles or adults could be affected by the intake stream were they in the vicinity of the intake.

Ning et al. (2019) reviewed the entrainment risk of juvenile and adult redfin perch and gambusia. They found that redfin perch 82 – 221 mm long were weak swimmers with a maximum sustained swimming speed of juvenile to large individuals of only 0.15 m/s. Swimming speeds of gambusia were less than this. Hence, juveniles and adult redfin perch and gambusia would potentially be at risk of entrainment if they were within the intake stream. Large juvenile or adult trout, however, would have a lower risk of entrainment, given the cruising speed of trout is much faster, with juvenile trout swimming speeds having been estimated at 0.5 m/s, and faster for adults (Fry & Cox, 1970). This risk would be considered to be similar to the existing level of exposure to entrainment through current operations from the intake at T3 power station.

It is considered 'likely' that there would be some entrainment of some life-history stages of salmonids located near the intake. Trout cod, which are stocked within the reservoir, and other native species could also be entrained, although the likelihood is reduced to 'unlikely' due to the expected low abundance of these species, evidenced by the fact that none were captured during surveys for this assessment.

The area over which fish could be entrained would be considered small relative to the total size of the reservoir. Further, the unnatural, dark and long passage provided by the intake tunnel would likely deter fish of all ages and size classes from entering the structure (NSW DPI, 2016b). The location of the intake below the littoral zone, away from any substantial vegetation, which would otherwise likely be utilised as habitat, would also deter fish from entering it.

Given Murray crayfish live on the reservoir floor rather than in the water column, have not been located at depths equivalent to the base of the intake, and any individuals located within the intake would be translocated prior to construction, the likelihood of entrainment is considered to be 'unlikely'.

The small number of native fish, invertebrates or salmonids likely to be entrained would not be expected to amount to an adverse change to the populations of these species (i.e. the consequence would be 'insignificant') and the impact would be considered equivalent to that already experiences at T3 power station and other intakes located within the Snowy Scheme. Hence, the overall risk of entrainment to these groups is low (**Table 6-7**).

Impacts on KFH, Threatened Species and EECs

Talbingo Reservoir is Type 1 KFH (**Section 5.3.8**). No EECs occur within Talbingo Reservoir.

No impact on KFH is anticipated as a result of the operation of the Snowy 2.0 station.

Threatened and protected species that have potential to occur within the vicinity of the proposed intake areas at Talbingo Reservoir include:

> Murray crayfish (*Euastacus armatus*) – listed as vulnerable under the FM Act; and

> Trout cod (*Maccullochella macquariensis*)(stocked population) - endangered under the FM Act and EPBC Act.

The likelihood and consequence of entrainment of the various life stages of these species are discussed above, with the risk to both species from entrainment into the intakes being low.

Key Threatening Processes

The risk of entrainment is not designated a key threatening process.

7.2.2.3 Tantangara Reservoir

Direct Impacts – Entrainment of biological material.

1. Phytoplankton and zooplankton

The phytoplankton community of Tantangara Reservoir is described in **Section 5.4.7**. Information on zooplankton potentially occurring in the reservoir has been inferred from other studies.

As described for Talbingo Reservoir (**Section 7.2.2.2**), in Tantangara Reservoir the peak biomass of different phytoplankton groups may be expected at different depths in relation to the thermocline, which occurs in late spring to summer between 5 and 10 m below the reservoir surface. In Tantangara Reservior, however, the water clarity restricts the photic zone to within a few metres of the surface, and as such, it is expected that bulk phytoplankton biomass is within the surface layers (i.e. within the top few metres within the photic zone). Given the top of the intake is proposed t be approximately 17.5 m below FSL and 8.5 m below MOL most phytoplankton biomass would be above the depth of the intake particularly when the reservoir level is high.

The risk to zooplankton may be greater given its potential to be in deeper water for part of the day. Given the thermocline in Tantangara Reservoir is generally at about 5-10 m, it is not clear if the DVM of zooplankton would extend to the hypolimnion. Notwithstanding this, given DVM of zooplankton would be expected to extend to some depth below the surface during the day, a proportion of the vertical extent of the bulk of zooplankton would potentially be within the water layers potentially affected by the intake stream at some times during the year. There is no evidence to suggest that concentrations of plankton would be particularly greater at the intake compared to other areas. Notwithstanding this, it is expected that some plankton would be entrained.

Importantly, given the large volume of the reservoir, the likely average daily abstractions would be a small fraction of the total volume of reservoir water. This means the relative proportion of total plankton with the potential to be entrained is low. Given the large natural variability in plankton concentrations observed within the reservoirs, it is likely that any impacts would be minor. This risk is also similar to the existing risk of entrainment at other tunnel and power station intakes throughout the scheme. In addition, some proportion of plankton entrained and transferred to Talbingo may be returned or replaced during pumping. As a result, the overall risk of entrainment to plankton is 'moderate' (**Table 7-2**).

1. Fish and invertebrate

a) Eggs

The freshwater fish occurring in Tantangara Reservoir include introduced brown and rainbow trout and native mountain galaxias as well as the common yabby and Reik's crayfish. None of these species, however, spawn pelagic eggs that would be potentially at risk of entrainment at the Snowy 2.0 intake within Tantangara Reservoir (**Table 7-1**).

Some soft sediment macroinvertebrates are the only biota occurring or potentially occurring in Tantangara Reservoir that spawn pelagic or semi buoyant eggs (**Table 7-1**), which would drift with water flow and hence would have potential for entrainment. As these eggs have a high turnover and the number affected would be a very small proportion of the total volume, the impact on these and eggs in general, is expected to be insignificant and the risk is therefore considered to be low (**Table 7-2**).

b) Larvae

As for Talbingo, it is considered 'likely' that some fish larvae within the immediate area in front of the intake could be entrained, although the bulk of these would likely be salmonids. As for plankton, given the large volume of the reservoir, the potential daily abstractions would be a small fraction of the total volume of reservoir water so the relative proportion of total larvae with the potential to be entrained is low with the consequence considered to be 'insignificant' leading to a low risk of impact. This risk is considered similar to the existing risk of entrainment at other tunnel and power station intakes throughout the Snowy Scheme.

c) Juvenile and adults

The top of the intake in Tantangara is estimated to be at least 9 m below the water surface at MOL and will often be significantly greater. Juveniles and adults of the native and non-native species known to occur in Tantangara Reservoir are typically found in littoral habitat or in the top layers of the water column rather than the very deep waters of the reservoir. Although the depth of the intake would be outside the area considered to be preferred habitat, some areas of occupancy of all species in the reservoir would potentially overlap with the upper areas of the intake stream (particularly when the reservoir was operating close to MOL).

As a result, it is considered 'likely' that there would be some entrainment of some life-history stages of salmonids located near the intake. Mountain galaxias could also be entrained, although the likelihood is reduced to 'unlikely' due to the expected low abundance of these species, evidenced by the finding that none were captured during surveys for this assessment.

The area over which fish could be entrained would be considered small relative to the total size of the reservoir. Further, the unnatural, dark and long passage provided by the intake tunnel would likely deter fish of all ages and size classes from entering the structure (NSW DPI, 2016b). The location of the intake below the littoral zone, away from any substantial vegetation, which would otherwise likely be utilised as habitat, would also deter fish from entering it.

Given freshwater crayfish would live on the reservoir floor rather than in the water column and have not been located at depths equivalent to the base of the intake, the likelihood of entrainment is considered to be 'unlikely'.

The number of native fish, invertebrates or salmonids likely to be entrained would not be expected to amount to an adverse change to the populations of these species (i.e. the consequence would be 'insignificant') and the impact would be considered equivalent to that already experienced at other power station and tunnel intakes located within the Snowy Scheme. Hence, the overall risk of entrainment to these groups is low (**Table 7-2**).

Impacts on KFH, Threatened Species and EECs

Tantangara Reservoir is a Type 2 KFH (**Section 5.4.8**). No EECs or threatened species occur within Tantangara Reservoir. No impact on KFH is anticipated as a result of the operation of the Snowy 2.0 station.

Key Threatening Processes

The risk of entrainment is not designated a key threatening process.

7.2.2.4 Mitigation Measures and Residual Risks

The risk of harm to biota from entrainment into the Snowy 2.0 intakes at Talbingo and Tantangara reserviors is considered to be comparable to the existing risk posed by T3 power station in Talbingo and at other station intakes throughout the scheme and is considered to be 'low'. There are no specific mitigation measures proposed to reduce the likelihood and consequences of entrainment. The residual risk of entrainment on aquatic receptors within each of the reservoirs is 'low' (**Table 7-2**).

Table 7-2 Qualitative risk assessment of likelihood and consequences of entrainment during operational water transfer before and after proposed mitigation. L=Likelihood of occurrence; C = Consequence of occurrence. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Direct - Hydraulic entrainment and entrapment of biota	Talbingo Reservoir	Threatened aquatic species – trout cod	Unlikely	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species – Murray crayfish	Unlikely	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Likely	Insig	Low	Likely	Insig	Low
		Salmonids	Likely	Insig	N/A	Likely	Insig	N/A
		Planktonic assemblages	Likely	Insig	Low	Likely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Likely	Insig	Low	Likely	Insig	Low
		Salmonids	Likely	Insig	N/A	Likely	Insig	N/A
		Planktonic assemblages	Likely	Minor	Moderate	Likely	Minor	Moderate

Worst case likelihoods for entrainment of egg, larvae or juvenile/adult life-history stages considered.

7.2.3 Fish Transfer

7.2.3.1 Description of Impacting Processes

Snowy 2.0 would establish a bi-directional hydrologic connection between Talbingo Reservoir and Tantangara Reservoir that would result in the inter-basin transfer of water and potentially fish. Potential impacts associated with this process include:

- Introduction of species to areas where they are currently absent;
- Transfer of genetic material between currently isolated populations resulting in the loss of genetic diversity and / or species; and
- Transfer of pathogens associated with fish. This is considered in **Section 7.2.5**.

Ning et al. (2019) were commissioned by Snowy Hydro to investigate the potential survival of various life-history stages of redfin perch and of adult eastern gambusia through the proposed pumped hydro system. This was undertaken via a series of laboratory experiments and modelling that simulated various conditions and scenarios of pumping from Talbingo to Tantangara reservoirs. This included simulated blade strike, shear stress and pressure change. In addition to surviving passage through the pipeline and station, the likelihood of redfin perch or eastern gambusia reaching Tantangara is also dependant on them becoming entrained at the intake. This would depend on conditions at the intake, such as intake velocity, and factors related to fish behaviour and swimming speeds and presence of different life-history stages near the intake (impacts of entrainment are assessed in **Section 8.2.2**). Overall, Ning et al. (2019) concluded that based on the results of their experiments and modelling, a proportion of redfin perch or eastern gambusia should they be entrained at the intake in Talbingo Reservoir could survive the shear, blade strike and pressure impacts expected to occur within the pumped hydro system (Ning et al. 2019). Whether redfin and eastern gambusia will be entrained into the intake and survive transfer through the completed development cannot be known with certainty until Snowy 2.0 becomes operational. In absence of this, the assessment is based on the experimental results.

No data were available on survival of other fish species known to be present in Talbingo Reservoir and no studies were undertaken on the likelihood of survival of fish during the transfer of water from Tantangara to Talbingo in generation mode. Thus, as a precautionary approach this assessment has assumed the potential for any species currently present in either reservoir to survive transport through the pumped hydro system. In the absence of any information to the contrary, an assumption of survival (of at least some individuals) has also been applied to other biota (e.g. crayfish, zooplankton and phytoplankton).

7.2.3.2 Preventing Fish Movements

The potential for fish transfer between catchments as a result of Snowy 2.0 was identified early in the Project, with the primary concern relating to the transfer of redfin perch (and other pest species) from

Talbingo Reservoir to Tantangara Reservoir. THA (2019) were engaged by Snowy Hydro limited to undertake a review of options to prevent the entrainment of redfin perch at Snowy 2.0.

Potential physical methods investigated for preventing the potential entrainment of redfin perch at the Talbingo intake included static screens, travelling screens and barrier nets. Where screens are fine enough, passage of small fish, including larvae, and eggs, can be blocked. Behavioural deterrents such as light and sound were also considered as well as other options such as elimination of redfin perch from Talbingo Reservoir, electrical deterrence and euthanasia.

Given the design features of Snowy 2.0, and based on the findings of the review, flat-panel wedge-wire screens, drum screens and submerged water intake, fish-friendly (SWIFF) screens were considered technically feasible (THA, 2019). These options would all require significant civil works. In the case of drum and SWIFF screens this would include the construction of forebays and screen chambers. These civil works would likely extend the construction footprint of the intake works beyond the existing boundary and require considerable volumes of additional excavation at each of the intakes with associated high construction costs and environmental impacts. Based on preliminary design work, none of these options was considered feasible and they are not proposed as part of the Project.

It was, however, identified that the potential impact of fish transfer, particularly pest species, could be mitigated via the installation of fish barriers that would limit the potential range expansion of pest species from Tantangara Reservoir into other catchments. Hydrologic connections from Tantangara Reservoir include releases to the Mid Murrumbidgee River catchment through Tantangara Dam and diversions to Lake Eucumbene through the Murrumbidgee-Eucumbene Tunnel (M-E Tunnel) (**Figure 5-1**). The design of Snowy 2.0 includes a screening system capable of preventing fish transfer via these pathways. Further detail about the system can be found in **Section 6.4**.

Further, to prevent the potential movement of climbing galaxias into the Upper Tantangara Creek Catchment where stocky galaxias are found, a specially designed fish barrier is proposed in Tantangara Creek just upstream of the waterfall upstream of Alpine Creek Trail. This barrier is designed to prevent movement of climbing galaxias into the upstream 4 km of Tantangara Creek above the waterfall where it may impact stocky galaxias. Further detail about the barrier can be found in **Section 6.4.1.5**.

Catchments with the potential to be directly affected by the movements of fish between Snowy 2.0 are referred to as ‘primary catchments’ and include Talbingo Reservoir, Tantangara Reservoir and their immediate upstream catchments. Any of the catchments located downstream of the reservoirs and the proposed fish transfer controls (or in the case of Upper Tantangara Creek, upstream), are described as ‘secondary catchments.’ As a result of the barrier controls the risk of transfer of fish to secondary catchments as a result of Snowy 2.0 is considered ‘rare’ and would only be expected to occur in the event of a failure of controls, or in the case of the mid-Murrumbidgee, if a spill from the reservoir occurs.

The current risk of spill from Tantangara is very small. Snowy Hydro has developed methods for managing the head ponds of its generation storages. The combination of flexible, remotely controlled assets and in-house weather forecasting skill has ensured that there has never been an uncontrolled spill of the Snowy Scheme’s generation headponds (i.e. Geehi, Tumut Pond and Talbingo reservoirs). The change in Tantangara’s operating function from a large diversion and storage pond to the headpond for Snowy 2.0 would be accompanied by a significantly increased diversion capacity and flexibility to integrate with the rest of the Scheme’s operation to manage spill risks.

The diversion capacity of the Murrumbidgee-Eucumbene Tunnel is 20 m^3/s in pressure flow operation. The diversion capacity of Snowy 2.0 will be approximately 380 m^3/s. Ignoring the river outlet gate, which is subject to daily release targets as set out by the Snowy Water Licence, the maximum capacity that can be routinely relied on to divert water out of Tantangara Dam would be 400 m^3/s (34.5 GL/d).

The highest recorded historical daily inflow into Tantangara Reservoir is 21 GL (March 2012). This is equivalent to a 1:60 year Annual Exceedance Probability (AEP) flood. The peak inflow to the reservoir on that day is estimated to have been approximately 350 m^3/s. The maximum recorded 3 and 7 day inflow volumes of 40 GL and 80 GL respectively (also in March 2012 flow event). Had the same historical event occurred with Snowy 2.0 in place, the event could have been managed in its entirety from any starting storage level.

Currently without Snowy 2.0, a 3 day event of a 1:100 AEP magnitude with peak inflows approaching 1000 m^3/s could be managed to avoid a spill. With the additional diversion capacity afforded by Snowy 2.0, even with a conservatively high start storage level of 80% the day before the event, a 1:2000 AEP flood, with peak inflows approaching 2000 m^3/s, would also be manageable without spill.

The ability to manage inflows through Snowy 2.0 is dependant on the station being available for service, and sufficient airspace being available in Talbingo, Jounama and Blowering reservoirs to receive discharges. The likelihood of a full station outage impacting diversion capability over 3 days (conservatively estimated at 3 days in 25 years) coincidental with a 3 day 1:100 AEP inflow event is considered to be extremely rare.

Snowy Hydro has discretion over the airspace and release rates from Talbingo and Jounama reservoirs, with the ability to discharge 1100 m^3/s from Tumut 3 power station. Blowering Reservoir, which is downstream of Jounama pondage, has a very large storage at 1630 GL total active capacity. Snowy Hydro has the ability to forecast potential spill risk months in advance and can proactively manage releases into the Tumut valley and nominate an airspace in Blowering Reservour to manage inflows of comparable volumes to those set out above

7.2.3.3 Primary catchments

The primary catchments that could be reached by fish transferred between Talbingo and Tantangara reservoirs are Tantangara Reservoir, watercourses upstream of Tantangara Reservoir (the Upper Murrumbidgee River Catchment),Talbingo Reservoir and connected upstream watercourses (the Yarrangobilly River Catchment and Upper Tumut River Catchment) **(Figure 7-1**). No primary control measures that are feasible and 100 % effective have been identified that would prevent transfers to these areas (**Section 7.2.3.2**). The areas are:

> Area 1: Tantangara Reservoir up to full supply level (FSL). Access would be possible if fish survived entrainment and passage through the pumped hydro system from Talbingo Reservoir;

- Likelihood of transfer:
  - Likely: redfin perch, rainbow trout, brown trout (widespread and abundant in Talbingo Reservoir; can occur with depth range of the intake)
  - Possible: wild goldfish (apparent relatively lower abundance)
  - Unlikely:
    - Eastern gambusia (abundant, but largely restricted to shallow shorelines);
    - Murray crayfish (apparent preference for water < ~ 15 m deep);
    - Trout cod, Flat headed gudgeon and common yabby (could occur at intake depth; but small population in Talbingo);
    - Two-spined blackfish, mountain galaxias, climbing galaxias (preference for stream habitat, likely small population in Talbingo Reservoir; climbing galaxias may spawn in reservoir, but only along shallow shorelines).

> Area 2: Watercourses upstream Tantangara Reservoir. Fish would reach these areas if they survived passage to Tantangara Reservoir and were able to move upstream into connected flowing watercourses;

Area 2a: All watercourses upstream of Tantangara Reservoir in the upper Murrumbidgee River catchment, including Upper Murrumbidgee River, Tantangara Creek and, Nungar Creek, etc. but excluding upper Tantangara Creek upstream of the waterfall at Alpine Creek Trail crossing (addressed as a separate catchment):

- Likelihood of transfer:
  - Possible: Redfin perch; Although not preferred habitat and considered relatively poor swimmers compared with many native fish in the study area, this species has been caught in shallow riffle sections of Yarrangobilly River and Wallaces Creek and in several other watercourses in the Study Area, which suggests they can use such habitat;
  - Unlikely: Climbing galaxias, mountain galaxias, two-spined blackfish, flat-headed gudgeon, salmonids and Murray crayfish. These species are considered unlikely to be transferred into Tantangara, but if this occurred could possibly migrate upstream as they prefer or are known to occur in lotic habitats;
  - Rare: Eastern gambusia and wild goldfish. These species are considered unlikely and possible to be transferred into Tantangara Reservoir, though would not be expected to move into upstream flowing watercourses. These species prefer lentic habitat (and were not caught in Yarrangobilly River or Wallaces Creek). Their ability to move at least a small distance upstream into lotic habitat, however, cannot be excluded.

- Area 2b: Goodradigbee River (in the Lower Murrumbidgee River Catchment) via Goodradigbee River Aqueduct, a buried concrete pipeline, that transfers water from the Goodradigbee River weirlpool to Tantangara Reservoir:
  - Likelihood of transfer:
    - Rare: climbing galaxias, although it has potential to move upstream past obstacles that would be barriers to other species, the 3.7km long, enclosed pipeline is highly unlikely to be suitable for active passage of this species;
    - Not considered possible: all other species.

> Area 3: Talbingo Reservoir and connected watercourses in the Yarrangobilly River and Upper and Lower Tumut River catchments. Fish would reach these areas if they are entrained and survived passage from Tantangara Reservoir to Talbingo Reservoir:

- Area 3a: Talbingo Reservoir up to FSL. Fish would reach here if they are entrained in Tantangara Reservoir during power generation and survive passage through the pumped hydro system.
  - Likelihood of transfer:
    - Likely: Rainbow trout and brown trout (relatively abundant in Tantangara Reservoir most likely to occur at depths comparable to the intake).
    - Unlikely: Mountain galaxias and Reik's crayfish (prefer lotic habitat and likely to have small populations in Tantangara Reservoir).
- Area 3b: Watercourses upstream of Talbingo Reservoir (Yarrangobilly River and upper Tumut River Catchment). Fish could reach these areas if they survived transfer to Talbingo Reservoir and were able to move upstream into connected flowing watercourses.
  - Likelihood of transfer:
    - Unlikely: Mountain galaxias and Reik's crayfish. Both species have small populations in Tantangara and are unlikely to be transferred in sufficient numbers to establish populations that would subsequently move upstream.

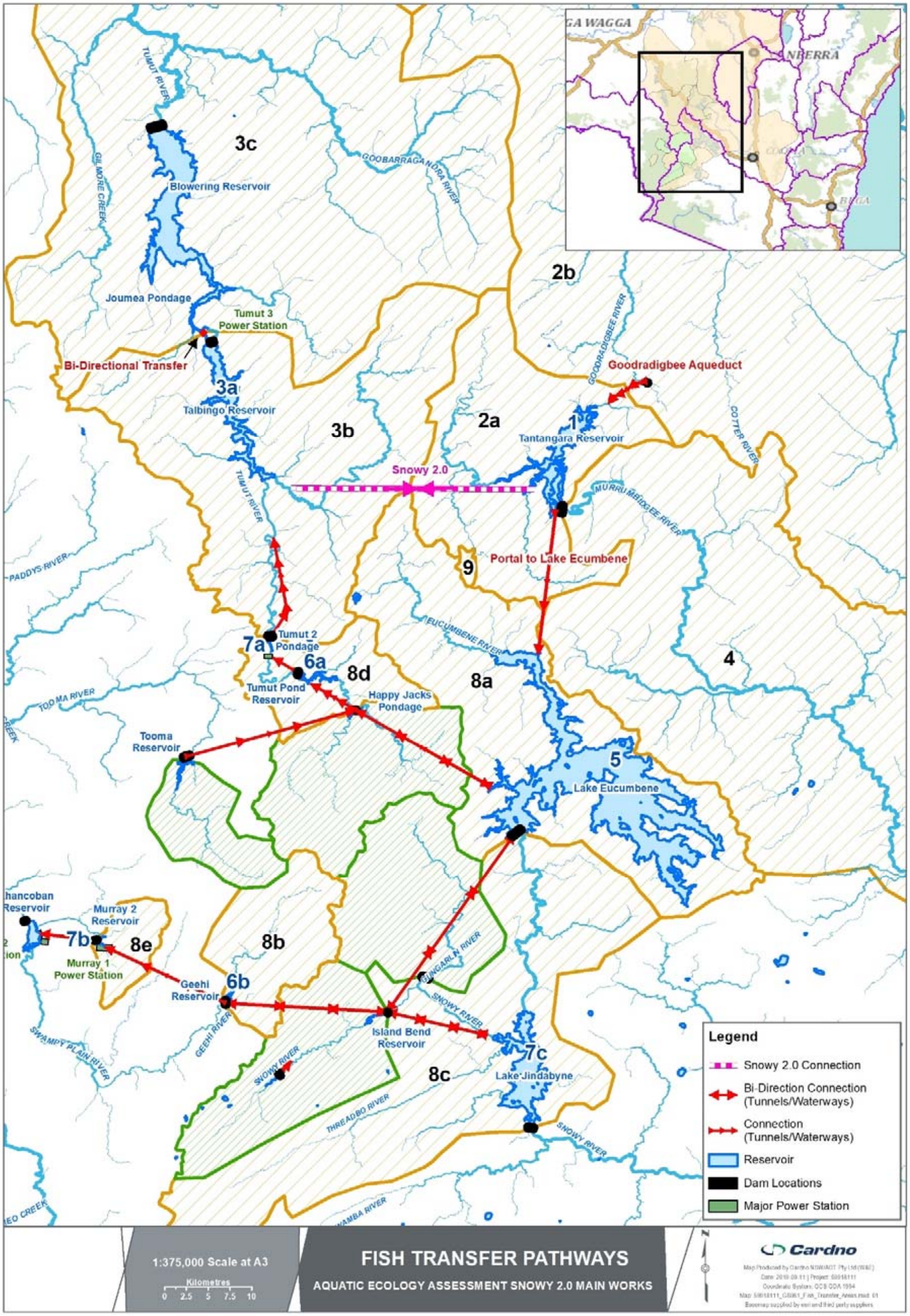

Figure 7-1 Conceptual diagram of the existing Snowy Hydro Scheme connections and the proposed Snowy 2.0 connections overlaid with possible fish incursion areas (in the event of no barrier mitigation) and areas that would not be accessible.

Tantangara Reservoir

Non-native species considered to occur in Talbingo Reservoir but not in Tantangara Reservoir include redfin perch, eastern gambusia and wild goldfish. Native species include trout cod, Murray crayfish, two-spined blackfish, climbing galaxias and flathead gudgeon. Species considered present in both reservoirs include brown trout, rainbow trout and mountain galaxias (**Sections 5.3** and **5.4**).

Redfin perch

As discussed above, the possibility of live transfer of redfin perch through Snowy 2.0 cannot be excluded and no reasonable and feasible measures to prevent this have been determined (**Section 7.2.3.2**).

The duration and severity of impacts associated with the transfer to redfin perch to Tantangara Reservoir would depend on the number of individuals that are transferred and their potential to establish a self-sustaining population in the reservoir. A self-sustaining population would likely result in greater number of redfin perch (due to natural recruitment) and an ongoing presence of redfin perch. It is unclear how many redfin perch would be required to establish a self-sustaining population, though it is not inevitable that all introductions would result in establishment. For example, inadvertent introductions of redfin perch (in batches of trout fingerlings) in the Canberra region did not result in establishment (Lintermans, 2004). It is noted also that introductions could occur irrespective of the Project, and redfin perch have been known to be introduced to areas via 'bait-buckets' and use of live bait, contaminants in fish stocking, escapes from outdoors ponds and dams, deliberate and illegal stocking and transfer via fishing gear (Lintermans, 2004). The current presence of redfin perch in the Canberra region is reported to have occurred due to legal stocking, deliberate illegal stocking and subsequent escape from stocked locations during high flows and use of live bait (Lintermans, 2004).

Two key factors influencing the potential for Redfin perch to become established in Tantangara Reservoir are the availability of suitable spawning habitat and water temperature. Redfin perch typically deposit eggs on structural habitat such as wood debris and aquatic plants but may use other types of structure if available (NSW DPI, 2019d). Tantangara Reservoir provides far less such structural habitat than does Talbingo Reservoir, though it is possible redfin perch may be able to utilise other structures that have been identified during site visits, such as bedrock and submerged terrestrial vegetation.

Water temperature would also influence the survival and successful reproduction of redfin perch. Data indicates that redfin perch can tolerate water temperatures ranging from 0 °C to 30 °C (Baumgartner, et al., 2017). The temperature profile of Tantangara Reservoir (approximately 4°C to 25°C) is within the thermal tolerance of redfin perch. Modelling undertaken using a range of environmental predictors indicated that although habitat suitability is marginal, redfin perch could survive in Tantangara Reservoir and many of the surrounding tributaries (Baumgartner, et al., 2017). Fluctuations in water levels in Tantangara Reservoir may inhibit natural recruitment by exposing and causing the desiccation of eggs laid adjacent to the shoreline. Regardless, it is considered possible that individual redfin perch transferred to Tantangara Reservoir could establish a self-sustaining population.

There is potential for redfin perch to predate on Reik's crayfish, common yabby and mountain galaxias. Common yabbies are not native to either reservoir (rather, they are considered translocated populations), and, in any case, common yabby is able to co-occur with redfin perch in Talbingo Reservoir. Thus, impacts to common yabby would likely be insignificant. Due to common yabby not being native to either reservoir, specific impacts are also not considered further in this assessment. The potential impact on Rieks crayfish is less certain as there are no known reports of co-occurrence of these two species. The apparent low abundance of Reik's crayfish in Tantangara Reservoir would, however, suggest the overall effect on the wider catchment population due to predation in Tantangara Reservoir would be minimal.

Redfin perch would be expected to affect populations of salmonids in Tantangara Reservoir via predation on smaller trout and competition for other food resources. Complete displacement of brown or rainbow trout from Tantangara Reservoir, however, is not expected.

Eastern gambusia

Eastern gambusia have a lower likelihood of entrainment through Snowy 2.0 due to their preference for shallow habitats, though the possibility of transfer of live eastern gambusia through Snowy 2.0 cannot be excluded.

Eastern gambusia prefer lentic and slow-flowing lotic environments and, whilst they originated in sub-tropical areas, have shown remarkable adaptive abilities and can exist in cold-water environments (DEWHA, 2008). There are reports of this species surviving temperatures as cold as 1 °C to 5 °C (at least for short periods) (DEWHA, 2008; Pyke, 2005 and references therein). A population of eastern gambusia occurs in Talbingo

Reservoir, where water temperature 1 m below the surface during winter ranges from 6 °C to 8 °C (Cardno, 2019). It is unclear if the slightly colder winter water temperature 1 m below the surface in Tantangara Reservoir (range: 4 °C to 5 °C; 2018 data) would prevent the establishment of eastern gambusia in Tantangara Reservoir. Based on examination of their environmental tolerances and conditions in Tantangara Reservoir, it is considered possible that eastern gambusia may establish a permanent population within the reservoir, if they become entrained and survive transfer.

Eastern gambusia are highly predatory, but due to their small size are capable of consuming only very small prey items, such as larval fishes, aquatic insects, other small invertebrates and tadpoles (NSW DPI, 2019e). Eastern gambusia may also damage larger individuals via fin nipping and their aggressive behaviour may alter the distribution of native fish (DEWHA, 2008). Eastern gambusia may affect mountain galaxias in Tantangara Reservoir by fin nipping and predation of eggs and larvae. Given the likely small population of mountain galaxias present in Tantangara Reservoir, substantial impacts to the wider population are unlikely. It is also unlikely that there would be impacts on Reik's crayfish in the reservoir.

Wild goldfish

No information was available on the potential for wild goldfish to survive transfer between the two reservoirs, thus for this assessment it is assumed that transfer would be possible. Wild goldfish prefer warm, slow-flowing lowland rivers or lakes, though they are also known from slower-flowing reaches of upland rivers (Lintermans, 2007). They are omnivores, eating plants, insects such as mosquito larvae, small crustaceans, zooplankton, and detritus (Street, 2019). While Tantangara Reservoir may be sub-optimal habitat for goldfish (based on the relatively lower abundance of structural habitat such as aquatic vegetation and wood debris), the similarities in temperature between the two reservoirs (see redfin perch above) would suggest Tantangara Reservoir would also provide for the temperature requirements of wild goldfish (reported to survive 0 °C - 30 °C (Street, 2019)). Overall, the threat of significant ecological impacts following the transfer of wild goldfish into Tantangara Reservoir is assessed as low. They are not expected to prey on native species of fish there, though they are thought to contribute to poor water quality due to the disturbance of soft substratum whilst feeding. Such changes in water quality are not expected to have any more than insignificant consequences for native species in the reservoir. This species is generally regarded as a 'benign' introduction to Australia (Lintermans, 2007).

Salmonids

No information was available on the potential for salmonids to survive transfer between the two reservoirs, thus for this assessment it is assumed that survival would be possible. Genetic mixing of these currently geographically isolated populations could occur, though associated potential changes in genetic diversity in these species are not expected to result in the loss of unique lineages of brown or rainbow trout. In particular, salmonids are likely to share a large degree of genetic information given they are derived from similar brood stock. Thus, associated impacts are likely to be insignificant.

Climbing galaxias

No information was available on the potential for climbing galaxias to survive transfer between the two reservoirs, thus for this assessment it is assumed that survival would be possible. Climbing galaxias occur in the Yarrangobilly River, and, although no individuals were found in Talbingo Reservoir, they have potential to occur there due to the direct hydrological connection (**Annexure B**). Although a native species, they are considered translocated to the Murray-Darling Basin.

Climbing galaxias have been linked to the decline and probable extinction of Pedder galaxias (*Galaxias pedderensis*) in Lake Pedder, Tasmania and the loss of the common river galaxias (*Galaxias vulgaris*) in streams above Lake Mahinerangi in New Zealand (Chilcott et al, 2013). The loss of Pedder galaxias is purported to have occurred due to the combination of predation and competition by brown trout and climbing galaxias, which were introduced into the lake when it was flooded and inundated by another headwater catchment. Although no Pedder galaxias were found in the stomach contents of climbing galaxias, larvae of another galaxiid, swamp galaxias (*Galaxias parvus*) were found (it was possible the rarity of Pedder galaxias contributed to the absence in the stomach contents of these fish).

If they are transferred from Talbingo Reservoir, it is possible that they would become established in Tantangara Reservoir. The habitat of Tantangara Reservoir and its tributaries is not, however, expected to provide optimal habitat for climbing galaxias. In coastal streams, climbing galaxias have been reported to spawn in the interstices of cobbles and pebbles adjacent to riparian vegetation inundated during floods (O'Conner & Koehn, 1998). Between subsequent flood events, eggs may be exposed to the air for several days, reportedly up to 7 m from the water edge. When exposed, eggs and streamside substratum remained damp, shaded by riparian vegetation. Hatching would occur 30 days to 60 days later when eggs were inundated by a subsequent flood. The (semi) terrestrial deposition of eggs may also act as an avoidance mechanism, protecting them against aquatic predators such as adult climbing galaxias and juvenile salmonids (O'Conner & Koehn, 1998). Riparian cover may be important in providing shaded and moist conditions for the survival of eggs in the wild (O'Conner & Koehn, 1998). Although the periodic changes in water levels in Tantangara Reservoir could mimic natural flood events, the absence of substantial riparian vegetation in the reservoir and in watercourses upstream could hinder, though not necessarily prevent, reproduction and establishment of climbing galaxias in these areas.

If transferred to Tantangara Reservoir climbing galaxiid may compete and possibly prey on mountain galaxias. Such impacts in the reservoir are, however, not expected to be substantial in the context of the wider catchment given that the population in the reservoir appears to be small.

Mountain galaxias

The taxonomy of galaxiids in Tantangara Reservoir and in the Upper and Mid Murrumbidgee River catchments is uncertain (See **Annexure B** for a detailed discussion). Raadik (2018) tentatively identified individuals captured in the Upper and Mid Murrumbidgee catchment as *G. olidus*, although he noted morphological variation between specimens from the Upper and Mid Murrumbidgee River catchments and between these specimens and reference specimens from nearby populations of mountain galaxias. Genetic variability was also identified within the *Galaxias* genus; the haplotype detected in Talbingo Reservoir (assumed to belong to *G. olidus* based on known distributions of galaxiids) was distinct from that detected in Tantangara Reservoir and that detected in the Upper and Mid Murrumbidgee River catchments by EnviroDNA (2019a) (**Annexure B**).

Whether the two populations in the Upper and Mid Murrumbidgee River are mountain galaxias as tentatively identified, or alternatively, represent either one or two separate undescribed species within the mountain galaxias cryptic species complex, has important implications for the consideration of impacts. If these populations represent separate species distinct from mountain galaxias, consequences of the Project for either population are much greater (i.e. the potential extinction) than loss of local populations of a widespread species. There is potential for mountain galaxias that are transferred from Talbingo Reservoir to compete with or interbreed (resulting in loss of genetic diversity) with individuals within Tantangara Reservoir. Thus, although galaxiids are considered present in both Talbingo Reservoir and Tantangara Reservoir, transfer of individuals from Talbingo Reservoir could lead to genetic mixing of two currently isolated populations.

Other native species

Trout cod, Murray crayfish, two-spined blackfish and flathead gudgeon are all considered present in Talbingo Reservoir but not, as far as is known, in Tantangara Reservoir. Trout cod are stocked in Talbingo Reservoir, though it is not known if they reproduce and form a self-sustaining population there. It is unclear if they would become established in Tantangara Reservoir if transferred from Talbingo Reservoir. No accounts of the potential for survival of freshwater crayfish passing through a pumped hydro system were found for this review. Given the apparent small populations of all of these species in Talbingo Reservoir (none were captured during surveys for this assessment) the likelihood of entrainment and establishment in Tantangara Reservoir is unlikely.

If transferred, there is potential for these other native species to interact with mountain galaxias and Reik's crayfish in Tantangara Reservoir. Any impacts are, however, less likely to occur and would likely result in less severe consequence than those associated with potential transfer of redfin perch. It is possible that any Murray crayfish transferred to Tantangara Reservoir may compete with Reik's crayfish, though again, impacts are unlikely to be substantial in the context of the wider catchment due to the apparent small population of Reik's crayfish in Tantangara Reservoir and the likely low rate of transfer (if at all) of crayfish from Talbingo.

Upper Murrumbidgee River Catchment

Any fish transferred into Tantangara Reservoir may then move into watercourses flowing into the reservoir if they are able to move past the riffles, runs and natural barriers present within the catchment and if these streams provide suitable habitat. Streams in this catchment include the Upper Murrumbidgee River, Tantangara Creek, Nungar Creek and Mosquito Creek. The species considered present in these catchments are the same as in Tantangara Reservoir, with the exception of the Upper Tantangara Creek Catchment (**Section 5**).

Redfin perch may be able to move at least a short distance into the Upper Murrumbidgee River, possibly some of its tributaries (e.g. Tantangara Creek) and at least the lower sections of other watercourses, such as Nungar Creek and Mosquito Creek. They would be unable to pass the existing waterfall on Tantangara Creek upstream of which stocky galaxias are present. The habitat provided in the watercourses upstream of

Tantangara Reservoir is likely to be sub-optimal for redfin perch and the extent of upstream movement is likely to be hindered or blocked by natural barriers such as cascades and large riffle sections. Redfin perch are reported to have relatively poor swimming ability, with mean maximum sustained swimming speeds of 0.15 m/s (SD: 0.00) and burst swimming speeds of 0.32 m/s (SD: 0.02), slower than two species of galaxiid (*Galaxias maculatus* and *Galaxias truttaceus*), congolli (*Pseudaphritis urvillii*), and non-native brown trout (*Salmo trutta*) (Davies, 2000). These estimates were consistent for redfin perch in the length range of 82 mm to 221 mm (fork length). It is unclear if such velocities would be exceeded in some or all of the watercourses flowing into Tantangara Reservoir.

Redfin perch were found in riffle sections in Yarrangobilly River and Wallaces Creek as part of this assessment and they have been caught streams elsewhere in the Study Area (Lintermans, 2019; NSW DPI, 2017; **Annexure B**), indicating that they can use these lotic habitats, though it is unclear how far upstream redfin perch would be able to move. While it is noted that individuals in these watercourses may be at least partly derived from historic introductions into these watercourses, particularly around Lobs Hole in the Yarrangobilly Catchment where there was historic settlement, regardless, the presence of individuals in shallow riffle sections of Yarrangobilly River and Wallaces Creek indicates they are able to use such habitat. Therefore, it is reasonable to expect that at least some individuals would move upstream from lentic habitats at least some distance into flowing watercourses. Visual assessment suggests similarities in morphology and flow (riffle-pool sequences, range in water depth and apparent flow velocities) of watercourses in the Upper Murrumbidgee River Catchment is comparable to that of Yarrangobilly River and Wallaces Creek. Those caught in these watercourses tended to be smaller adult fish juveniles and it is possible smaller fish could swim upstream through shallow sections that larger adults could not.

Eastern gambusia and wild goldfish both prefer lentic habitats and neither was found in Yarrangobilly River nor Wallaces Creek upstream of their known occurrence in Talbingo Reservoir. It is considered unlikely they would be able to penetrate and become established in the watercourses of the Upper Murrumbidgee Catchment. They would likely be unable to swim against strong currents or be capable of penetrating beyond fast-flowing, shallow stream sections. The swimming ability of poeciliid fish (the family of fish to which eastern gambusia belongs) is also relatively poor, and was estimated at 14.1 cm/s (range 4.9 cm/s to 22.3 cm/s) (Srean, et al., 2016) and for *G. affinis* burst swimming speed up to 33.2 cm/s (Jiangtao, et al., 2017). Notwithstanding the above assessment, both species may be able to occupy localised lentic habitat provided by deeper pools in the Upper Murrumbidgee River Catchment.

Given the reputed abilities of climbing galaxias to negotiate natural obstacles (McDowell, 1996) it would have the potential to establish in most watercourses within the Upper Murrumbidgee River Catchment if transferred to Tantangara Reservoir.

Redfin perch

If successfully transferred, Redfin perch would be expected to prey on juvenile rainbow and brown trout within the Upper Murrumbidgee River Catchment, however, the extent to which redfin perch would penetrate watercourses in the Upper Murrumbidgee River Catchment would be limited. Combined with predation on salmonids expected to occur within Tantangara Reservoir, this could contribute to a reduction in the population size of salmonids. Redfin perch may also predate on mountain galaxias in the Upper Murrumbidgee River Catchment. The potential for this would be related to the geomorphic characteristics of watercourses between Tantangara Reservoir and the population of mountain galaxias (only confirmed occurrence is near the confluence of Murrumbidgee River and Tantangara Creek). Although the galaxiids specimens identified at these locations are sympatric with salmonids and are able to tolerate associated impacts (primarily predation), at least to some extent, this does not necessarily indicate they would be able to tolerate predation by redfin perch, or be able to persist whilst experiencing the cumulative effect of predation from both species

If redfin perch are transferred from Talbingo Reservoir to Tantangara Reservoir, and are able to penetrate into watercourses of the Upper Murrumbidgee River Catchment where mountain galaxias occur, potentially, this population would be lost. If a unique species is present, the potential consequence could represent loss of a species (i.e. a catastrophic consequence) rather than a local population (i.e. a major consequence). As discussed above in the case of Tantangara Reservoir, the more conservative position has been considered in the risk assessment. Finally, redfin perch may prey on Reik's crayfish, particularly smaller individuals, in the Upper Murrumbidgee River Catchment. Given this is the preferred habitat of Reik's crayfish, the consequences may be greater importance than any occurring in Tantangara Reservoir (where the apparent population size is smaller), though loss of the population would not be expected (i.e. moderate consequence).

Eastern gambusia and wild goldfish

The likelihood of eastern gambusia and wild goldfish penetrating beyond the mouths of inflowing streams and resulting in substantial impacts to native species is considered rare. Any impact is also less likely and would be less severe than any associated with redfin perch.

Climbing galaxias

If transferred to Tantangara Reservoir, climbing galaxias would likely have the ability to migrate into inflowing watercourses potentially resulting in competition and possible predation on mountain galaxias. As noted above, considering the potential for a distinct species to occur any impact to this population has been assessed as a catastrophic consequence. Such an impact is not certain, and climbing galaxias and other galaxias species, including mountain galaxias, are known to co-exist in a number of locations. Therefore, the likelihood of complete loss of the population/species is considered conservatively as ‘possible’. As is the case for redfin perch, impacts due to potential competition and predation from climbing galaxias may be exacerbated in the presence of impacts currently experienced due to predation from salmonids.

Talbingo Reservoir, Yarrangobilly River Catchment and Upper Tumut River Catchment

The only species that is considered to occur in Tantangara Reservoir that is not already present in Talbingo Reservoir and surrounding inflowing catchments is Reik’s crayfish Species considered present in both reservoirs include brown trout, rainbow trout and mountain galaxias (**Sections 5.3** and **5.4**).

Reik’s crayfish

No accounts of the potential for survival of freshwater crayfish passing through a pumped hydro system were found for this review. Reik’s crayfish reportedly occurs in bogs, creeks and rivers (AAB, 2019) and its occurrence at altitudes above 1,000 m suggests that habitat conditions within Talbingo Reservoir would be sub-optimal. The presence of Murray crayfish in Talbingo Reservoir suggests the potential for competitive interactions with Reik’s crayfish. Given its apparent habitat preference of Reik’s crayfish, and the likely small population in Tantangara Reservoir, the likelihood of large numbers being transferred to Talbingo Reservoir and for significant competitive interactions to occur with Murray crayfish are unlikely. Reik’s crayfish appear to prefer lotic habitats; Murray crayfish have broader habitat preferences. The larger size of Murray crayfish would also likely confer a competitive advantage over Reik’s crayfish, and the natural distribution of these species appears to overlap in the Mid Murrumbidgee River (**Annexure B**). Transfers of Reik’s crayfish into Talbingo Reservoir is unlikely to affect other native species or salmonids in Talbingo Reservoir.

Mountain galaxias

As noted above, there is some uncertainty around the taxonomy of the mountain galaxias present in the Upper and Mid Murrumbidgee catchments. If individuals in Tantangara Reservoir are a separate species, transfer to Talbingo Reservoir could result in hybridisation and / or genetic mixing with mountain galaxias in Talbingo Reservoir. They may also compete with mountain galaxias for resources. Whilst present in the Upper Murrumbidgee River Catchment, the inferred small numbers in Tantangara Reservoir (based on absence in field surveys, low relative abundance of DNA, and apparent preference for riffle habitat where these fish can probably avoid predation from salmonids) would suggest the likelihood of them being entrained and transferred to Talbingo Reservoir is unlikely. Any transfer of mountain galaxias from Tantangara Reservoir to Talbingo Reservoir is unlikely to affect other native species or salmonids in Talbingo Reservoir.

Salmonids

As noted for Tantangara above, potential impacts associated with mixing of the different salmonid populations within each of the reservoirs would be insignificant.

7.2.3.4 Secondary Catchments

Based on the various artificial connections and barriers (dams and weirs), the Snowy Hydro scheme can be grouped into areas based on the number of connections and subsequent transfers that would need to occur for the fish to arrive at each catchment. Transfer of fish may involve passive and / or active movement. The likelihood of entrainment of each species at each reservoir would depend on the potential for individuals to occur within the zone of influence of the intake, their swimming ability and escape potential at each life-history stage. Fish occurring in the reservoirs, near the intakes and at depths subject to strongest inflow velocity would be most at risk of entrainment. The more abundant a species, and the slower and more weakly it can swim, the greater the potential for entrainment and transfer. Additionally, the likelihood of “successful” transfer would diminish as the number of transfer pathways (e.g. through tunnels and power stations) increases.

If entrainment and passage through the pumped hydro system occurs, further transfer into connected watercourses may be associated with active movement (i.e. against the flow of water to upstream watercourses) or combined active and passive movement (i.e. with the flow of water through tunnels and power stations into downstream watercourses). The likelihood of a species to move upstream would depend their habitat preferences, ability to swim against the flow of water and ability to negotiate potential barriers (e.g. riffles). The likelihood of a fish moving downstream through a reservoir or power station intake would depend on the same factors discussed in the entrainment section above (**Section 7.2.2**). Importantly, most tunnel inlets that connect the scheme reservoirs will be located at depths at or below the proposed Snowy 2.0 intakes and are thus located at depths that are outside the expected depth preferences of most species.

As noted in **Section 7.2.3.2**, a fish screen system at Tantangara Reservoir been integrated into the project that are expected to prevent the downstream movement of all fish into the Mid and Lower Murrumbidgee Catchments and prevent any movement of fish in to Lake Eucumbene. A barrier is also proposed near the waterfall on Tantangara Creek to prevent any movement of climbing galaxias into the habitat of the stocky galaxias in upper Tantangara Creek. As a result of these controls, the likelihood of transfer of fish to any locations connected to Tantangara is rare.

In the event that live fish are transferred from Talbingo Reservoir to Tantangara Reservoir and fish barrier controls at Tantangara Reservoir fail, fish could enter the catchments of several river systems (**Figure 7-1**), including the Upper, Mid and Lower Murrumbidgee River, Snowy River and Murray River catchments. The assessment presented here considers first the impacts expected to occur in an un-mitigated (i.e. no barrier controls) scenario, though the likelihood of fish being transfer beyond Tantangara Reservoir is considered remote given the proposed controls (**Section 7.2.3.2**).

The potential for fish present in Blowering Reservoir Catchment and the Lower Tumut River Catchment below Talbingo Reservoir dam wall (Area 3c in **Figure 7-1**) to be affected by transfer of mountain galaxias and Reik's crayfish from Talbingo Reservoir (following potential transfer from Tantangara Reservoir) is expected to be less likely than any that could occur in Talbingo Reservoir. Far fewer would be transferred below Talbingo dam wall than would be transferred to Talbingo Reservoir from Tantangara Reservoir (if any). The potential transfer of mountain galaxias and Reik's crayfish to Talbingo Reservoir is expected to have negligible impacts on other species downstream of Talbingo Reservoir dam wall (including Murray cod, silver perch and golden perch).

No impacts are expected to occur to species of fish in the Murray River Catchment or in the Lower Snowy Catchment as redfin perch, eastern gambusia and wild goldfish already occur in these areas. Alpine redspot dragonfly (present in the Lake Jindabyne, Swampy Plain River and Geehi Reservoir / M2 Reservoir catchments) is also not expected to experience impacts associated with fish transfer as predation and competition from fish are not considered threats to alpine redspot dragonfly.

In an un-mitigated scenario, assuming transfer from Talbingo Reservoir to Tantangara Reservoir (**Section 7.2.3.3**), there is potential for fish to be transferred from Tantangara Reservoir to the Mid Murrumbidgee River via Tantangara Reservoir dam wall / spillway and to the Snowy River and Murray River catchments via the M-E Tunnel. These areas are:

- Area 4: Mid-Murrumbidgee River Catchment downstream from Tantangara dam wall. Fish would reach there if they were entrained and survived passage from Talbingo Reservoir and passage via environmental release or spill through Tantangara Reservoir.
  - Potential transfer: redfin perch and climbing galaxias (also the Lower Murrumbidgee Catchment). Eastern gambusia and wild goldfish may also be transferred (though only to the section of the Mid Murrumbidgee River between Tantangara dam wall and approximately Adaminaby),
- Area 5: Lake Eucumbene up to FSL. Fish would reach here if they were entrained and survived transfer from Talbingo Reservoir and then passage through the M-E Tunnel.
  - Potential transfers: mountain galaxias, two-spined blackfish, trout cod, redfin perch and eastern gambusia, Murray crayfish.
- Area 6:
  - Area 6a: Tumut Pond Reservoir in the T2 Reservoir Catchment. Passage dependent on entrainment and survival through the pumped hydro system, the M-E Tunnel and the Eucumbene-Tumut tunnel.
    - Potential transfers: trout cod, two-spined blackfish, redfin perch, eastern gambusia.
  - Area 6b: Geehi Reservoir. Passage dependent on entrainment and survival through the pumped hydro system, the M-E Tunnel, the Eucumbene-Snowy tunnel and Snowy-Geehi tunnel.

  - Potential transfers: trout cod, two-spined blackfish, mountain galaxias, redfin perch, eastern gambusia and Murray crayfish (though possibly relatively unlikely).

> Area 6:

- Area 7a: Tumut 2 Pondage. Passage dependent on entrainment and survival through the pumped hydro system, the M-E Tunnel, the Eucumbene-Tumut tunnel into Tumut Pond Reservoir and entrainment and survival through Tumut 1 power station.
  - Potential transfers: trout cod, two-spined blackfish, redfin perch and eastern gambusia.
- Area 7b: Murray 2 Reservoir. Passage dependent on entrainment and survival through the pumped hydro system, the M-E Tunnel, the Snowy-Geehi tunnel to Geehi Reservoir and entrainment and survival Murray 1 power station.
  - Potential transfers: trout cod, two-spined blackfish, mountain galaxias, redfin perch, eastern gambusia and Murray crayfish (though possibly relatively unlikely).
- Area 7c: Lake Jindabyne up to FSL. Passage dependent on survival through the pumped hydro system, the M-E Tunnel and either:
  - o Entrained through the Eucumbene-Snowy and Snowy-Geehi tunnel to Geehi Reservoir then subsequently back through the Snowy-Geehi tunnel and Jindabyne-Island Bend tunnel and out through the Jindabyne pumping station bypass into the Snowy River arm of Jindabyne Reservoir.
  - Potential transfers: trout cod, two-spined blackfish, redfin perch and eastern gambusia
  - o Through the Eucumbene Adit Riparian release valve at Eucumbene Dam Wall (Maximum capacity 0.07 m^3/s, typical release 0.03 m^3/s) into the Eucumbene River. Note: the likelihood of any species being transferred through this structure would be considered rare to impossible.
  - Potential transfers: none, considered rare to impossible for all species.

> Area 8: Watercourses upstream of Areas 5 to 7. Passage dependent on entrainment and survival through the pumped hydro system, the M-E Tunnel and were able to move upstream into connected flowing watercourses as described below:

- Area 8a: Watercourses upstream of Lake Eucumbene (including the Upper Eucumbene River Catchment);
- Area 8b: Watercourses upstream of Geehi Reservoir (Geehi River and its tributaries);
- Area 8c: Watercourses upstream of Lake Jindabyne (including Snowy River to Island Bend Dam wall, Thredbo River and lower sections of Snowy River and its tributaries below dams and weir structures);
- Area 8d: Watercourses upstream of Tumut Pond Reservoir (including the Tumut River to Happy Jacks Reservoir dam wall and associated tributaries (Temperance Creek, Nine Mile Creek and Clear Creek); and
- Area 8e: Watercourses upstream of Murray 2 Reservoir (including Khancoban Back Creek and Broken Back Creek).
  - Potential transfers: any species transferred to each lake / reservoir. The potential for transfer of eastern gambusia to flowing watercourses is, however, likely to be relatively low due to the unsuitability of this habitat for this species.

> Area 9: Upper Tantangara Creek upstream of the waterfall at Alpine Creek Trail crossing. Climbing galaxias may reach this area if they are entrained and survive transfer through the pumped hydro system into Tantangara Reservoir and are able to migrate above the existing waterfall:

  - Potential transfers: climbing galaxias (no other species are expected to have the potential to move upstream of the waterfall on Tantangara Creek).

Regardless of the installation of the barriers described in **Section 7.2.3.2** fish would be unable to access the following areas due to artificial barriers or unidirectional connections:

> Happy Jacks Reservoir, Happy Jacks Creek and the headwaters of the upper Tumut River. This is due to Happy Jacks Dam that would prevent upstream movement of any fish transferred to Tumut Pond Reservoir from Lake Eucumbene;

- The Snowy River Catchment upstream of Island Bend Dam wall, including Island Bend Reservoir, Guthega Reservoir and Blue Lake. Water is not transferred upstream of Island Bend Dam wall. The Gungarlin River (a tributary of the Snowy River downstream of Island Bend Reservoir) upstream of Gungarlin Dam weirpool wall would also not be accessible; and
- Tooma Reservoir and upstream catchment. The connection between this reservoir and Tumut Pond Reservoir is unidirectional (Tooma Reservoir to Tumut Pond Reservoir).

Upper Tantangara Creek Catchment

Upper Tantangara Creek is the only known habitat of the stocky galaxias. The waterfall at the base of this catchment appears to prevent upstream movement of all other fish. This would include all species with the potential to be transferred to Tantangara, with the exception of climbing galaxias. Due to their purported climbing ability, it is considered likely that if transferred, climbing galaxias may have the ability to move upstream of the waterfall on Tantangara Creek to where stocky galaxias occur. If this occurred, potential interactions with stocky galaxias include competition for resources and possibly predation, with the potential for complete displacement of stocky galaxias. The proposed barrier upstream of the waterfall on upper Tantangara Creek (**Section 7.2.3.2**) would prevent the movement of climbing galaxias to this section of the watercourse and remove the likelihood of climbing galaxias entering the habitat of stocky galaxias. The residual risk to stocky galaxias following the implementation of the barrier control would be moderate. Ongoing monitoring would be undertaken to confirm the efficacy of the barrier.

Mid and Lower Murrumbidgee River Catchments

Water from Tantangara Reservoir is released to the Mid and Lower Murrumbidgee River catchments through the river outlet works at Tantangara dam wall for environmental purposes and to maintain Cooma's water supply. Currently, water may also be released over the ungated spillway in the event that the level of the reservoir exceeds FSL. With the construction of Snowy 2.0, the ability to manage water levels and uncontrolled releases will be greatly increased to the point where the likelihood of a spill is considered extremely rare. As discussed in **Section 6.4.1.5**, following the implementation of a fish barrier at the river outlet works, the transfer of any fish downstream is not expected and the likelihood of transfer of any species to these catchments is considered 'Rare'.

Based on survey records, stocking and the results of predictive habitat mapping, several threatened and other native species of fish occur in the Mid Murrumbidgee River catchment. These are the threatened Macquarie perch, Murray cod, trout cod and Murray crayfish. Southern pygmy perch may also occur in the Numeralla River (a tributary of the Mid Murrumbidgee River). Several other native species also occur in the mid Murrumbidgee River Catchment: mountain galaxias, golden perch, two-spined blackfish, Australian smelt, flathead gudgeon, carp gudgeons and Reik's crayfish. Each of these species as well as dwarf flathead gudgeon, and the threatened silver perch and Murray-Darling Basin population of eel-tailed catfish also occur in the Lower Murrumbidgee River Catchment, although their distributions may be patchy and restricted to certain tributaries and habitats. The exceptions are southern pygmy perch and Reik's crayfish. The macro-crustaceans freshwater glass shrimp (*Paratya australiensis*) and freshwater prawn (Family: Palaemonidae) were also identified in the Mid Murrumbidgee River (**Annexure B**), though they are not considered separately as part of this assessment.

The taxonomy of galaxiids in the Upper and Mid Murrumbidgee River catchments is uncertain (**Section 7.2.3.3** and **Annexure B**). If a species distinct from mountain galaxias, the galaxias identified in the Mid Murrumbidgee River Catchment below Tantangara Reservoir dam wall may have a restricted distribution in this section of the catchment. Alternatively, it may represent an additional record of the mountain galaxias already identified in other surveys and locations.

Redfin perch are considered absent from the Mid Murrumbidgee River Catchment, presumed to be due to the presence of natural barriers to upstream movement from where they are known to occur in the ACT. Eastern gambusia and wild goldfish have been recorded from the Mid and Lower Murrumbidgee Catchment. However, they may not occur upstream of approximately Bolaro (approximately 4 km northeast of Adaminaby) in the case of eastern gambusia, and Kissops Flat (approximately 25 km southeast of Adaminaby) in the case of wild goldfish (**Annexure B**). Thus, it is possible that one or more natural barriers to upstream movement of these species is present. Transfer of these species from Tantangara Reservoir could result in their introduction and potential establishment upstream of Adaminaby (although this is considered rare following installation of the proposed barrier described in **Section 8.2.3.2**). It may also be the case that this section of the Mid Murrumbidgee River is unsuitable for these species. In which case, establishment may not be possible. Regardless, Snowy 2.0 would not result in the extension of the range of these species downstream of these areas. Increases in the abundances of these species where they currently occur and the potential for associated impacts are considered very unlikely, and diminish with distance downstream from Tantangara dam wall (and are expected to be negligible within the Lower Murrumbidgee River Catchment).

The climbing galaxias is considered absent from the Murrumbidgee River upstream of Lake Burrinjuck (i.e. the Lower and Mid Murrumbidgee River). The transfer of this species below Tantangara Reservoir dam wall could result in interactions with native galaxiids present in the Mid and Lower Murrumbidgee River. A further transfer pathway to the lower Murrumbidgee catchment exists via potential access to the Goodradigbee River via the Goodradigbee Aqueduct which connects to Tantangara Reservoir, should climbing galaxias be transferred to Tantangara. Given the length and conditions expected along the aqueduct, potential transfer via this pathway is considered remote. Although climbing galaxias is considered to be present downstream of Burrinjuck dam wall, due to its identification in the Tumut River Catchment, it is unclear if climbing galaxias would be able to move upstream of this structure.

Redfin perch

The potential severity of associated impacts to native species in the Mid Murrumbidgee River would depend, among other things, on the number of individuals of non-native species transferred, the duration of transfers and the persistence of fish in the Mid Murrumbidgee River once transferred. Although the Mid Murrumbidgee River would probably provide sub-optimal habitat compared with lotic environments, it does support structural habitat including wood debris suitable for spawning, at least in slower flowing pool sections, and the establishment of a self-sustaining population of redfin perch here cannot be ruled out. The likelihood is, however, considered rare given the controls described in **Section 7.2.3.3**. It is also unclear how many redfin perch would be required to establish a self-sustaining population (**Section 7.2.3.3**).

Transfer of redfin perch to the Mid Murrumbidgee River, in the event of a failure of the proposed barrier or a rare spill event, would be expected to result in interactions with Macquarie perch, Murray cod, trout cod and the non-native brown trout and rainbow trout due to competition for food and predation on juveniles and smaller individuals. Redfin perch could also compete with and / or predate on the other native species of fish and potentially also Murray crayfish.

Macquarie perch

Redfin perch have been linked with the decline in numbers of Macquarie perch further downstream in the Murrumbidgee River and in other catchments. The decline in abundance of Macquarie perch within Lake Eildon (Victoria) was attributed to the presence of redfin perch (Cadwallader & Rogan 1994) and the decline in abundance of Macquarie perch in the Murrumbidgee River is thought to be closely correlated with the increase in redfin perch in this waterway (NSW DPI, 2017). Redfin perch may impact Macquarie perch via competition for food, such as fish larvae and aquatic macroinvertebrates, and via direct predation on Macquarie perch larvae and small fish. There is considerable uncertainty in the outcome of such interactions in the Mid Murrumbidgee River. There may be potential for some level of co-occurrence. For example, while redfin perch and Macquarie perch may compete for resources, some degree of niche separation may be present. Redfin perch lay eggs in still water amongst plants/wood debris, while Macquarie perch lay eggs amongst gravel in flowing water. A lab study by Brown and Morgan (2015) indicated that Macquarie perch respond to the presence of redfin perch and tended to avoid larger redfin perch. This suggests that Macquarie perch respond to the potential threat of redfin perch and that Macquarie perch may avoid areas where redfin perch are present. Also, only younger Macquarie perch may be susceptible to predation due to size exclusion of larger individuals. This could suggest co-existence is possible, though no conclusive evidence of long-term redfin perch and Macquarie perch co-existence has been identified. Although Lintermans et al. (2013) includes records of Macquarie perch and redfin perch caught within the reservoir and riverine habitats of the Cotter River, it is unclear whether these species were caught in the same locations, and, if they were, their relative abundance. It is noted that coexistence in one locality does not necessarily indicate coexistence in another, with environmental conditions and the nature and extent of existing threats unlikely to be directly comparable. Identification of the two species in the same area also would not necessarily indicate stable population size trajectories (i.e. it is possible that a Macquarie perch population may be in the process of decline not detectable by a single survey event).

Despite the potential for niche separation and co-occurrence, in the absence of controls, predation and competition associated with redfin perch could result in a reduction in the population size of Macquarie perch in the Mid Murrumbidgee River Catchment. This reduction would likely also be associated with a greater susceptibility to the effects of existing and cumulative threats (including the presence of other existing predatory species, such as rainbow trout and brown trout, and river regulation and its potential influence on spawning cues and sedimentation). Given these considerations and many other potential uncertainties, the potential impact could range from a small reduction in population size up to the loss of the population in the Mid Murrumbidgee River Catchment.

The loss of this population would be a significant impact to this population and species as a whole. Such population level impacts would likely be relatively important for Macquarie perch at the scale of species given the few number of remaining self-sustaining populations and the apparent high levels of diversity and divergence observed across these populations (Faulks et al. 2010) and the potential loss of genetic diversity this could represent. Depending on the magnitude of any reduction in population size, this could also be a significant impact to this population and species as a whole. However, given the many uncertainties, not least the very low likelihood of transfer of redfin to this location, the potential reduction in population size likely to occur cannot be predicted with certainty. Given this and the known potential outcomes of previous interactions with Macquarie perch, and the high conservation significance of this population (i.e. a self-sustaining wild population), any reduction in population could have major consequences for Macquarie perch and represent a high risk both to the population and potentially the species. The residual risk to Macquarie perch following the implementation of the barrier control identified in **Section 7.2.3.2** would be moderate.

Murray cod

Redfin perch are likely to compete with Murray cod and prey on juvenile Murray cod in the Mid Murrumbidgee River. There is some correlation between high numbers redfin perch, and low numbers of native fish including Murray cod (NMCRT 2010) and recent apparent increases in cod number in NSW coincide with historically low numbers of redfin perch (and carp). It is possible that the apparently greater current distribution of Murray cod, which are also found in the Lower Murrumbidgee River Catchment along with redfin perch, assumedly representing some level of niche separation enabling some degree of coexistence, compared with Macquarie perch, may represent a greater overall resilience to redfin perch (and other non-native species). This may represent a greater resilience of this population to impacts associated with the potential introduction of redfin perch here, if it occurred. This is, however, speculative. Murray cod and redfin perch also co-occur in the Blowering Reservoir Catchment, though the Murray cod population here appears to be maintained primarily via stocking (**Annexure B**). Although one potential outcome following the introduction of redfin perch to this area is the displacement of Murray cod, this is probably less likely than the case of Macquarie perch. It should be noted also that although the population present in the Mid Murrumbidgee River is considered to be self-sustaining it is derived from stocked populations rather that wild populations and probably does not represent a source of genetic diversity of particular conservation value. Given that these species appear to coexist in the river immediately downstream, local extinction of the population due to introduction of redfin perch is probably less likely than is the case for Macquarie perch. Nevertheless, the introduction of redfin perch to the Mid Murrumbidgee River could be expected to result in impacts to Murray cod resulting in a reduction in population size. The residual risk to Murray cod following the implementation of the barrier control identified in **Section 7.2.3.2** would be moderate.

Trout cod

Trout cod also have the potential to be adversely affected by the introduction of redfin perch to the Mid Murrumbidgee River Catchment, in the rare event that they are transferred to this location. Though as is the case with Murray cod, it is possible that the apparently greater current distribution of trout cod, compared with Macquarie perch, may represent a greater overall resilience to impacts associated with the introduction of redfin perch (and other non-native species). Again, this is somewhat speculative, though is to some degree supported by the apparent coexistence of trout cod and redfin perch further downstream in the Lower Murrumbidgee River Catchment. As is the case with Murray cod, a potential outcome following the introduction of redfin perch to this area is the displacement of trout cod (though perhaps less likely than the case of Macquarie perch). Similarly, the population of trout cod in the Mid Murrumbidgee River is considered self-sustaining and is derived from a stocked rather than wild population, therefore probably not representing a source of genetic diversity of particular conservation value. Nevertheless, the introduction of redfin perch to the Mid Murrumbidgee River could result in impacts to the species that would manifest as a reduction in population size. The residual risk to trout cod following the implementation of the barrier control identified in **Section 8.2.3.2** would be moderate.

Southern pygmy perch

In the rare event that redfin perch are transferred to the mid Murrumbidgee catchment, and are able to migrate upstream into the Numeralla River (a tributary of the Mid Murrumbidgee River), they would be expected to prey on all life stages of southern pygmy perch (due to the small size of the latter), if it occurs there. Supporting evidence for this prediction is from Blakney Creek near Yass. All of the sites where there was a decrease in southern pygmy perch abundance during 2009 to 203 were where redfin perch had colonised in 2009 (NSW DPI, 2013). The only sites where there was an increase in southern pygmy perch abundance are the upper most sites of the creek where presumably redfin had not yet reached. There appeared to be a direct correlation with the increase in redfin perch and the decrease in southern pygmy perch. If a population of southern pygmy perch occurs in Numeralla Creek, there is potential for it to be displaced by redfin perch if they are transferred to the Murrumbidgee River and if they are able to move upstream into the Numeralla River. If there is a population of southern pygmy perch in Numeralla Creek, it would likely represent a wild and possibly self-sustaining population. It is noted that the presence of any population has not been confirmed, however, such uncertainty cannot inform the likelihood or consequence of potential impacts and this assessment is precautionary. Existing natural and artificial barriers on the Numeralla River may also be present that would prevent access by redfin perch.

Mountain galaxias

In the rare event that redfin perch are transferred to the mid Murrumbidgee catchment they would be expected to prey on the galaxiids present in the Mid Murrumbidgee River just downstream of Tantangara dam wall and individuals further downstream. Predation by redfin perch may exacerbate impacts that are likely currently experienced due to predation by salmonids, and that would likely be experienced due to any eastern gambusia transferred here from Tantangara Reservoir (see below). If a species distinct from mountain galaxias is present, it is possible that introduction of redfin perch in these areas could result in extinction. However, it is also possible that the mountain galaxias detected in field surveys for this assessment is also present further downstream of this location, including where pest species are present This could suggest that they would be somewhat resilient to any impacts associated with transfer of pest fish. It is conceivable that the several previous identifications of mountain galaxias lower downstream in the Murrumbidgee River (e.g. Gilligan, 2005; NSW DPI, 2017, Lintermans, 2019; **Annexure B**) represent observations of the species captured just downstream of Tantangara Dam wall. The residual risk to mountain galaxias following the implementation of the barrier control identified in **Section 7.2.3.2** would be moderate.

Other native species

If redfin are transferred from Talbingo Reservoir to Tantangara Reservoir, and then in the rare event that barrier controls in Tantangara Reservoir fail, other native species currently present in the Mid Murrumbidgee River Catchment would be expected to experience impacts associated with the introduction of redfin perch. It is difficult to predict the severity of impacts that would be experienced by different species. All of these are present also within the Lower Murrumbidgee River Catchment, and assumedly are able to coexist with redfin perch. Possible via some level of niche separation and avoidance behaviour, though albeit whilst experiencing some level of existing impact possibly manifesting in reduced population sizes. One possible exception is two-spined blackfish. Although not listed as threatened in NSW, it is listed as vulnerable in the ACT and there is a suggestion it is susceptible to threats including predation by non-native fish, including salmonids and redfin perch. Such predation may not necessarily result in displacement of two-spined blackfish. Salmonids, redfin perch and two-spined blackfish all occur in Talbingo Reservoir and the Yarrangobilly River Catchment (**Annexure B**), albeit the abundance of two-spined blackfish may be reduced due to predation. Redfin perch may also prey on younger Murray crayfish present in the Mid Murrumbidgee River. Although this would be expected to affect the population of Murray crayfish here, it appears that these species are able to coexist (based on their co-occurrence in Talbingo Reservoir and the Lower Murrumbidgee River Catchment). The residual risk to other native species following the implementation of the barrier control identified in **Section 7.2.3.2** would be moderate.

Salmonids

As is the case for watercourses in the Upper Murrumbidgee River Catchment, redfin perch would be expected to predate on salmonids in the Mid Murrumbidgee River Catchment, resulting in an associated decrease in the size of populations of rainbow trout and brown trout. Any reduction in the population size of salmonids is considered a low risk for native fish populations. The likelihood of impact to salmonids wold be reduced following the implementation of the barrier control identified in **Section 7.2.3.2**.

Eastern gambusia and wild goldfish

The introduction of eastern gambusia and wild goldfish to the short section of the Mid Murrumbidgee River Catchment where they currently appear absent (i.e. the section from approximately Adaminaby to Tantangara Dam Wall) could potentially affect the population of mountain galaxias immediately downstream of the dam if it is confirmed to be distinct from mountain galaxias in the catchment and if it is more susceptible to predation and competition than the species known to coexist further downstream. Possible threats include predation (at least potentially of eggs and / or larvae or via fin-nipping) from eastern gambusia. Such as impacts are likely to be less severe than those associated with redfin perch introduction and associated predation of possibly all life stages, in particular. The residual risk to all native species following the implementation of the barrier control identified in **Section 7.2.3.2** would be moderate.

As eastern gambusia and wild goldfish are known to occur in the Mid Murrumbidgee further downstream of here and in the Lower Murrumbidgee River there would not be new introductions of these species here due to the Project.

Climbing galaxias

Climbing galaxias are not known to occur in the Murrumbidgee River upstream of Lake Burrinjuck. If transfer from Talbingo Reservoir to Tantangara Reservoir occurs, and if the barrier controls in Tantangara Reservoir fail, it could be transferred to the Mid and Lower Murrumbidgee River, it is possible that climbing galaxias could compete with and potentially prey on mountain galaxias present in this catchment. There is evidence climbing galaxias can co-occur with mountain galaxias. For example, in Talbingo Reservoir and / or the wider Tumut River Catchment and also in the Snowy River Catchment in Victoria (Fulton & Hall, 2011). Though it is difficult to predict the outcome of such interactions, competition and potential predation from climbing galaxias has potential to result in substantial impacts (particularly cumulatively associated with impacts from other pest fish introduced here) to mountain galaxias, possibly resulting in extinction, if it is distinct from those known to occur further down in the catchment. The residual risk to mountain galaxias following the implementation of the barrier control identified in **Section 7.2.3.2** would be moderate. There would also remain the potential, albeit unlikely, for climbing galaxias to be introduced to the Mid Murrumbidgee River from Tantangara Reservoir via the Goodradigbee River Aqueduct to the Lower Murrumbidgee River. It is noted that climbing galaxias is present currently in the Tumut River Catchment, and potentially the Murrumbidgee River, downstream of Lake Burrinjuck, though it is unclear if it would be able to move upstream past the dam wall.

Snowy River, Murray River and Tumut River Catchments

As noted in **Section 7.2.3.2**, the controls proposed at the M-E Tunnel are expected to prevent the transfer and establishment of all species of fish that could be transferred to Tantangara Reservoir as part of the proposed Project. As such, the likelihood of transfer of any fish and consequent impacts to any species in the Lake Eucumbene Catchment is rare with the likelihood of subsequent transfer to connected locations more remote.

If transfer from Talbingo Reservoir to Tantangara Reservoir occurs, and if the barrier controls in Tantangara Reservoir fail, key species of concern with potential for transfer from Talbingo Reservoir to the Snowy River, Murray River and Tumut River (upstream of T2 Dam) catchments via Tantangara Reservoir and the M-E Tunnel are redfin perch and eastern gambusia. Climbing galaxias are considered present in these catchments. In the Snowy River Catchment, redfin perch is considered absent from Lake Eucumbene and Lake Jindabyne catchments. DNA from eastern gambusia has been detected in Lake Eucumbene and Lake Jindabyne, although the detection rate was low (**Annexure B**). The sections of the Murray River catchment which are hydrologically linked to Lake Eucumbene are the Geehi Reservoir / Murray 2 Reservoir catchments (redfin perch and eastern gambusia are considered absent) and the Swampy Plain River Catchment (eastern gambusia considered absent, Redfin are known to be present from a few kilometres upstream of Khancoban reservoir). A hydrologic connection also exists to the section of the upper Tumut River Catchment upstream of T2 Dam (including Tumut 2 Pondage and Tumut Pond Reservoir), where redfin and gambusia are also considered absent. Wild goldfish are present currently in the Snowy River Catchment.

In the event that they were transferred to Tantangara Reservoir and if controls at the M-E Tunnel failed, there would also be potential for native species (trout cod, Murray crayfish and two-spined blackfish) to be introduced to the Snowy River Catchment. Although present in Talbingo Reservoir and possibly the Upper Tumut River Catchment downstream of T2 Dam, trout cod is not considered present upstream of this dam, and could also be introduced. Murray crayfish is present in the Upper Tumut River Catchment (at least in T2 Reservoir) and the Swampy Plain River Catchment (it has been recorded from Khancoban Pondage), but could be introduced to the Geehi Reservoir / M2 Reservoir Catchment where it's current presence is unknown. Trout cod may also be introduced to the Geehi Reservoir / M2 Reservoir and Swampy Plain River catchments and two spined blackfish to the Geehi Reservoir / M2 Reservoir catchment.

Rainbow trout and brown trout are ubiquitous across these catchments. Atlantic salmon have also been stocked in the Lake Jindabyne and in the Swampy Plain River Catchment upstream of Khancoban Reservoir, and brook trout in Lake Eucumbene and Lake Jindabyne catchments. Native species of fish present in Lake Eucumbene and Lake Jindabyne Catchments are climbing galaxias, Australian smelt, flat-headed gudgeon and alpine spiny crayfish. Mountain galaxias and Australian smelt are also present in the Lake Jindabyne Catchment. The threatened Snowy River Population of river blackfish may occur in the Thredbo River and Eucumbene River in the Lake Jindabyne Catchment (based on predictive habitat modelling). It is also known to occur in the Lower Snowy River Catchment downstream of Jindabyne Dam Wall along with mountain galaxias. Murray crayfish, two-spined blackfish, mountain galaxias, flat-headed gudgeon, Reik's crayfish, alpine spiny crayfish and burrowing crayfish are present Swampy Plain River Catchment and mountain galaxias, Reik's crayfish, alpine spiny crayfish and burrowing crayfish in the Geehi

Reservoir / M2 Reservoir catchments. Climbing galaxias and common yabby are also present in the Swampy Plain and / or Geehi Reservoir and M2 Reservoir Catchments, but this is not their natural distribution.

In the very unlikely event of transfer, these species could be affected by the introduction of fish, particularly redfin perch, to these areas where they are currently absent.

Redfin perch

Should Redfin be transferred to Lake Eucumbene due to failure of all controls, there is the potential to impact rainbow trout and brown trout via predation. As is the case for Tantangara Reservoir, redfin perch may also establish in Lake Eucumbene (species distribution modelling indicated Lake Eucumbene could support redfin perch (Baumgartner, et al., 2017)) and the surrounding catchment. There could be substantial reductions in the number of juvenile and smaller salmonids in the reservoir (larger trout would likely avoid predation), resulting in moderate consequences for stocked salmonid populations here if this is not mitigated with additional re-stocking. Once in Lake Eucumbene, redfin perch may be transferred throughout sections of the connected Snowy Hydro System from which it is currently absent. This includes the upper Tumut River Catchment upstream of T2 Dam (including Tumut Pond Reservoir and T2 Reservoir), Lake Jindabyne Catchment and the Geehi Reservoir M2 Reservoir Catchment including Geehi River upstream of Geehi Reservoir, Murray 2 Pondage and watercourses upstream of Murray 2 Pondage. Once here, redfin perch could affect populations of rainbow trout, brown trout and other salmonids present in each of these areas, and Atlantic salmon in Lake Jindabyne. As is the case for other Tantangara Reservoir and the Upper and Mid Murrumbidgee River Catchments, predation by redfin would likely result in moderate consequences to these populations of salmonids. The residual risk to these fish following the implementation of the mitigation measures identified in **Section 7.2.3.2** would be moderate.

There is potential also for redfin perch to predate on native species of fish present in these areas. These include the threatened Snowy River Catchment population of river blackfish potentially present in the Eucumbene River between Lake Eucumbene and Lake Jindabyne and in the Thredbo River. If present, such impacts could result in major consequences for this species, given its apparent restricted distribution. Redfin perch may also predate on native climbing galaxias, mountain galaxias and flat-headed gudgeon present in the Lake Eucumbene and Lake Jindabyne catchments and mountain galaxias, flat-headed gudgeon and alpine spiny crayfish in the Swampy Plain River and / or Geehi Reservoir / M2 Reservoir catchment. Climbing galaxias is also present in, but not native to, the Murray River Catchments. Given the potentially large range extension of redfin perch throughout the Snowy River Catchment upstream of Jindabyne Dam Wall, and the conservation value of these fish (all flowing watercourses and their associated aquatic biota upstream of Lake Eucumbene and Lake Jindabyne are part of the Snowy River EEC), unmitigated, predation by redfin perch would constitute a high risk for these populations. The residual risk to these fish following the implementation of the mitigation measures identified in **Section 7.2.3.2** would be moderate.

Eastern gambusia

Although eastern gambusia would be expected to impact native aquatic fauna by consuming small prey (such fish larvae and insects), such impacts would likely be restricted to the margins of reservoirs where suitable still water and suitable refuge habitat would be available. This would limit their potential impact on native fish (as impacts would be restricted to these environments), and particularly those more likely to be found in flowing water environments (river blackfish), which may not be found in these habitats at all or rarely. They would be expected to colonise Lake Eucumbene, Lake Jindabyne, Geehi Reservoir, M2 Reservoir, Tumut Pond Reservoir, T2 Pondage and possibly Khancoban Pondage (if not present currently), but not their upstream flowing watercourses. Therefore, impacts to the Snowy River EEC (which does not include artificial impoundments) due to introduction of eastern gambusia are likely to be minor and associated only with a potentially relatively minimal movement of eastern gambusia into the mouths of some flowing tributaries. It is unclear if eastern gambusia are absent from the Swampy Plain River Catchment (redfin perch are present). If they are absent and are introduced to this catchment via transfers to M2 Pondage and Geehi Reservoir, impacts to native species in the Swampy Plain River Catchment (two-spined blackfish, mountain galaxias, flat-headed gudgeon, Murray crayfish, alpine spiny crayfish and burrowing crayfish could occur) are possible, though probably unlikely in the case of crayfish, which may even prey on eastern gambusia. Such impacts would, however, likely be relatively minor compared with any impacts these species currently experience associated with redfin perch. Particularly considering these species (except flat-headed gudgeon) have preferences for flowing water where these species would be most likely to occur. However, consequences are considered moderate given they could be long-term (i.e. associated with ongoing transfer and / or potential local establishment of species). The residual risk to these fish following the implementation of the mitigation measures identified in **Section 7.2.3.2** would be moderate.

Native species

The consequence of the very low potential for transfer of native species (native two-spined blackfish, trout cod, Murray crayfish) present in Talbingo Reservoir to the Snowy River and upstream sections of the Murray River and Tumut River catchments are expected to be minimal. While these species are not native to the Snowy River Catchment, they are unlikely to demonstrate pest-like characteristics (being habitat specialists, rather than generalists) that may otherwise result in any significant impacts (associated with potential predation and / or competition) to other native species and salmonids. One possible exception is two-spined blackfish. It is conceivable that if transferred to the Snowy River Catchment that this species may compete with the Snowy River Population of river blackfish (either the population known to occur downstream of Lake Jindabyne or any population present in Thredbo River or Eucumbene River, based on predicted distributions). In the Murray-Darling Basin, two-spined blackfish and the northern form of river blackfish appear to co-occur (apparently inhabiting different elevations and microhabitats). This does suggest that there is potential for co-existence in the Snowy Catchment. Given the conservation status of the river blackfish in the Snowy River Catchment, any associated impact, however, has potential to result in major consequences. In general, there is probably a very low potential for these native species to establish following introduction due to likely small numbers that would be transferred (based on their existing apparent low abundances in Talbingo Reservoir) and the presence of predatory species (mainly salmonids and redfin perch) that are currently present or that could also be transferred. A possible exception is Murray crayfish, which appears able to tolerate the presence of non-native fish in Talbingo Reservoir, and may be able to establish in Lake Eucumbene and Lake Jindabyne. It is uncertain, however, how likely Murray crayfish (and other crayfish) are to be entrained and transferred via Snowy 2.0. The residual risk to these fish following the implementation of the mitigation measures identified in **Section 7.2.3.2** would be moderate.

7.2.3.5 Key Threatening Processes

Potential transfer of fish via Snowy 2.0 may exacerbate the following KTPs:

> Introduction of fish to waters within a river catchment outside their natural range (FM Act);

> Novel biota and their impact on biodiversity (EPBC Act); and

> Predation by the Plague Minnow (*Gambusia holbrooki*) (BC Act).

The potential impacts on these KTPs have been discussed above.

7.2.3.6 Mitigation Measures and Residual Risks

The successful operation of the proposed fish barriers would substantially reduce the potential for the introduction of climbing galaxias to the Upper Tantangara Creek and the transfer of any fish out of Tantangara Reservoir into the Mid and Lower Murrumbidgee River catchments and to the Snowy River Catchment (and from there to the Murray River and Upper Tumut River catchments). As such, the likelihood of associated impacts occurring to native species and species of salmonids in these areas is very low. For Upper Tantangara Creek and the Snowy River, Murray River and Upper Tumut River Catchments, residual risks would be reduced as no other potential fish transfer pathways associated with the project are present.

A very small residual likelihood would still remain associated with the requirement for ongoing successful operation and maintenance of these barriers, in the event that pest species are transferred and establish in Tantangara Reservoir. Successful operation and maintenance would be required on an ongoing basis if self-sustaining populations of redfin perch and eastern gambusia develop in Tantangara Reservoir. For the population of wild Macquarie perch in the Mid Murrumbidgee River, in particular, this would necessitate ongoing monitoring for the potential for transfers and for associated impacts if transfer were to occur. There is also a very low potential for the project to result in the introduction of climbing galaxias to the Mid and Lower Murrumbidgee River via the Goodradigbee Aqueduct and River, irrespective of the barrier at Tantangara Dam Wall and of a spill event.

The assessment of reduced risk associated with fish transfer from Tantangara Reservoir to the Mid and Lower Murrumbidgee River would still retain a level of risk associated with the rare potential for a spill event overtopping the dam wall. With capability to manage spill events increased by Snowy 2.0, this is considered a rare. In the rare event it occurred, it could result in transfer of fish via a pathway independent of the environmental release and its proposed barrier. Mitigation measures outlined in **Table 7-5** would be implemented to control risks from fish transfer between reservoirs.

Table 7-3 Mitigation measures to control risks from fish transfer between reservoirs.

Mitigation Code	Description

AE17	Install a fish barrier on Upper Tantangara Creek designed to prevent upstream movement of climbing galaxias into stocky galaxias habitat
AE18	Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel
AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
AE04	A Weed, Pest and Pathogen Management Plan would be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.

It is considered that the residual risk associated with the transfer fish as a result of Snowy 2.0 operations would range between low and high (based on the assumed presence of a self-sustaining wild population (southern pygmy perch) and a conservative assumption that the mountain galaxias in the Upper and Mid-Murrumbidgee catchments represent one or two undescribed and narrow range species) or moderate otherwise (**Table 7-4**).

Table 7-4 Qualitative risk assessment of likelihood (L) and consequences (C) of impacts associated with transfer of fish as a result of Snowy 2.0. Impact of transfers on non-fish ecology due to transfers between Tantangara and Talbingo is considered minimal (see text) and is not included below. Add to risk table Mod=Moderate, Insig=Insignificant, Catas=Catastrophic.

Potential Hazard	Catchment	Receptor	Fish Stressor and Pathway	Before Mitigation			After Mitigation		
				L	C	Risk	L	C	Risk
Primary Catchments									
Impact of potential fish transfer on fish	Tantangara Reservoir	Threatened species	-	N/A	N/A	N/A	N/A	N/A	N/A
		Native species	Redfin perch Eastern gambusia Climbing galaxias Mountain galaxias (predation and competition)	Possible	Moderate	Mod*	Unlikely	Moderate	Mod*
		Salmonids	Redfin perch Eastern gambusia (predation)	Likely	Moderate	NA	Likely	Moderate	NA

Potential Hazard	Catchment	Receptor	Fish Stressor and Pathway	Before Mitigation			After Mitigation		
				L	C	Risk	L	C	Risk
	Upper Murrumbidgee Catchment (excluding upper Tantangara Creek)	Native species - Mountain Galaxias	Redfin perch and climbing galaxias (predation and competition)	Possible	Catastrophic	High*	Possible	Catastrophic	High*
		Other native species	-	N/A	N/A	N/A	N/A	N/A	N/A
		Salmonids	-	N/A	N/A	N/A	N/A	N/A	N/A
	Talbingo Reservoir, Yarrangobilly River Catchment and Upper Tumut River Catchment (below T2 Dam)	Threatened species - Murray crayfish	Reik's Crayfish (competition)	Unlikely	Insignificant	Low	Unlikely	Insignificant	Low
		Native species	Mountain Galaxias(competition and genetic mixing) Reik's Crayfish (competition)	Unlikely	Insignificant	Low	Unlikely	Insignificant	Low
		Salmonids	Salmonids (genetic mixing)	Possible	Insignificant	N/A	Possible	Insignificant	N/A
Secondary Catchments									
Impact of potential fish transfer on fish	Upper Tantangara Creek Catchment	Threatened Species - stocky galaxias	Climbing galaxias (predation and / or competition)	Likely	Catastrophic	Ext	Rare	Catastrophic	Mod
		Native species	-	N/A	N/A	N/A	N/A	N/A	N/A
		Salmonids	-	N/A	N/A	N/A	N/A	N/A	N/A
	Mid-Murrumbidgee River Catchment	Threatened Species - Macquarie perch	Redfin perch (predation and competition)	Possible	Major	High	Rare	Major	Mod
		Threatened Species - Murray cod, trout cod and Murray crayfish	Redfin perch (predation and / or competition)	Possible	Moderate	Mod	Rare	Moderate	Mod
		Threatened Species - Southern pygmy perch	Redfin perch (predation)	Possible	Major	High*	Rare	Major	Mod*

Potential Hazard	Catchment	Receptor	Fish Stressor and Pathway	Before Mitigation			After Mitigation		
				L	C	Risk	L	C	Risk
		Native species - Mountain galaxias	Redfin perch Climbing galaxias Eastern gambusia (predation and / or competition)	Possible	Catastrophic	High*	Rare	Catastrophic	Mod*
		Other native species	Redfin perch (predation)	Likely	Moderate	High	Rare	Moderate	Mod
		Salmonids	Redfin perch (predation)	Likely	Moderate	N/A	Rare	Moderate	N/A
	Snowy River Catchment	Threatened Population - River blackfish	Redfin perch (predation) Two-spined blackish (competition)	Possible	Major	High	Rare	Major	Mod
		Salmonids	Redfin perch Eastern gambusia (predation)	Likely	Moderate	N/A	Rare	Moderate	N/A
		Other native species	Redfin perch and eastern gambusia (predation)	Likely	Major	High	Rare	Major	Mod
		Snowy River EEC	Redfin perch and eastern gambusia (predation)	Likely	Major	High	Rare	Major	Mod
	Geehi Reservoir / M2 Reservoir Catchment	Threatened species	-	N/A	N/A	N/A	N/A	N/A	N/A
		Native species	Redfin perch Eastern gambusia (predation)	Likely	Moderate	High	Rare	Moderate	Mod
		Salmonids	Redfin perch Eastern gambusia (predation)	Likely	Moderate	N/A	Rare	Moderate	N/A
	Swampy Plain River Catchment	Threatened Species - Murray crayfish	Eastern gambusia (predation)	Unlikely	Moderate	Mod	Rare	Moderate	Mod
		Native species	Eastern gambusia (predation)	Unlikely	Moderate	Mod	Rare	Moderate	Mod
		Salmonids	-	N/A	N/A	N/A	N/A	N/A	N/A

*Preliminary risk assessments undertaken based on the assumed presence of a self-sustaining wild population (southern pygmy perch) and a conservative assumption that the mountain galaxias in the Upper and Mid-Murrumbidgee catchments represent one or two undescribed and narrow range species (see **Annexure B**).

7.2.4 Plant and Phytoplankton Transfer

7.2.4.1 Description of Impacting Processes

There are several direct and indirect processes via which the transfer of plants and phytoplankton via Snowy 2.0 operations could have potential to impact on aquatic habitats and associated biota within reservoirs and catchments. These include:

> Changes to the distribution and abundance of phytoplankton assemblages within both reservoirs (i.e. homogenisation of assemblages);

> Transfer of toxic by-products from algal blooms that could affect water quality;

> Increased potential for phytoplankton blooms to occur (i.e. some species transferred may be more prone to bloom/proliferate in their new reservoir/catchment);

> Potential to alter the composition of other aquatic biological components (i.e. bottom-up effect); and

> Potential for transfer of *Elodea* from Talbingo Reservoir.

7.2.4.2 Talbingo Reservoir

Phytoplankton, including Harmful Algal Blooms (HABs)

The phytoplankton communities of Talbingo and Tantangara reservoirs are described in **Sections 5.3.7** and **5.4.7**, respectively. Data collected during long-term sampling undertaken by Snowy Hydro (1998 to 2015) and data collected by Cardno in 2018 indicate some differences in the composition of the phytoplankton assemblages between reservoirs although the types of taxa present are broadly the same, but this was undertaken at a broad level of taxonomic resolution. There were some differences in overall abundance, with the abundance of phytoplankton tending to be greater in Tantangara Reservoir compared with Talbingo Reservoir. There was also evidence of an overall increase in abundance of phytoplankton in Tantangara Reservoir during 1998 to 2015 that that was not apparent in Talbingo Reservoir. Although the taxonomic resolution of the long-term surveys was relatively coarse, there was also indication of differences the relative abundance of taxonomic groups between reservoirs. Phytoplankton sampled by Cardno in 2018 were examined to a finer taxonomic resolution, allowing differences in assemblages between the reservoirs to be examined in more detail. These data suggest that there were some distinct differences in assemblages between the reservoirs and that some taxa were present in one of the two reservoirs only. These taxa include several diatoms and cyanobacters (blue-green algae), including *Dolichospermum circinale*, and an unidentified chlorophyte (green alga): these were sampled in Talbingo Reservoir, but not Tantangara Reservoir. Several chlorophytes, other cyanobacteria, including *Woronichinia* spp., and various other groups were also sampled in Tantangara, but not Talbingo Reservoir. Both *D. circinale* and *Woronichinia* spp., have been linked with harmful algal blooms (HABs). *Woronichinia* spp., may be a relatively new introduction to Australia, and is known to produce toxic blooms overseas. Chlorophytes may also form dense mats of algal filaments that can modify aquatic habitat.

Some phytoplankton may die when transferred between reservoirs (e.g., due to pressure changes that could rupture cells with gas vacuoles, including those in cyanophytes); others could be expected to survive, resulting in the transfer of viable phytoplankton between the reservoirs. Given the volume of water that would be transferred to Talbingo Reservoir from Tantangara Reservoir, it could be expected that phytoplankton taxa currently present in Tantangara Reservoir would be transferred to Talbingo Reservoir. If a toxic bloom did occur in one of the reservoirs, there may be a transfer of toxic by-products, irrespective of transfer of viable cells. If this occurred, those by-products would dilute rapidly in the receiving waters and would likely have negligible impact.

Thus, there may be three mechanisms by which HABs are transferred between reservoirs: transfer of viable toxic algae which cause a bloom in the receiving reservoir under suitable environmental conditions; transfer of toxic by-products from the sending reservoir into the receiving reservoir; or a combination of both mechanisms.

It is considered possible that taxa with the potential to form HAB, such as *Woronichinia* spp., could be transferred to Talbingo Reservoir from Tantangara Reservoir, with the potential for establishment there and perhaps in waterways further downstream.

There is an existing indirect pathway for phytoplankton transfer from Tantangara Reservoir to Talbingo Reservoir via transfers of water from Tantangara Reservoir to Lake Eucumbene, and from there to the upper Tumut River and Talbingo Reservoir via Tumut 1 and 2 power stations and associated reservoir connections. Even if viable cells are or have the potential to be transferred via the existing scheme, transfers between

Tantangara and Talbingo reservoirs as a result of Snowy 2.0, would constitute a much more direct route between them. Thus, there may be a greater number of cells transferred directly to Talbingo Reservoir via Snowy 2.0 than by the more indirect route described above.

The available data indicate that assemblages of phytoplankton currently differ between Talbingo and Tantangara reservoirs. Transfer of phytoplankton from Tantangara Reservoir to Talbingo Reservoir could result in changes to the phytoplankton assemblages in both reservoirs so that they more closely resemble each other. The extent to which this occurs, however, would depend on environmental conditions in each reservoir (e.g. different altitude, different depth, different seasonal climates, etc.). Changes in the phytoplankton assemblage may also affect other aquatic biota that consume or are otherwise associated with phytoplankton.

The results of the qualitative risk assessment for HABs are presented **Table 7-6**. Threatened aquatic species that could be affected include Murray crayfish and trout cod, both of which do or can occur within the reservoir. The likelihood of HAB taxa being transferred and for this to lead to a HAB at concentrations with the potential to impact biota within the reservoir is considered unlikely. If an impact were to occur, it would not be expected to threaten the entire population within the reservoir (and catchment streams) and recovery would be likely to occur following the bloom. This leads to an assessment of risk of moderate. The same assessment is applicable to all fish/crayfish in the reservoir including Murray crayfish and the stocked population of trout cod.

Changes to the phytoplankton assemblage in Talbingo Reservoir have the potential to alter the composition of other components of aquatic life in the reservoir. For example, changes in the composition of zooplankton, some of which feed on phytoplankton, could occur in response to changes to the abundance of difference phytoplankton groups. The exact nature of such changes cannot be predicted with confidence at this stage, however, it is considered that such changes are ‘possible’ and could lead to ‘minor’ consequences for these assemblages, which yields a risk assessment of Moderate (**Table 7-6**).

Proliferation of Non-native Aquatic Plants

Elodea is the only species of macrophytes identified to occurr in Tantangara Reservoir (**Section 7.2.4.3**). As this species is already present in Talbingo, it is therefore considered unlikely that Snowy 2.0 would lead to transfer of non-native aquatic plants into Talbingo Reservoir.

7.2.4.3 Tantangara Reservoir

Phytoplankton, including Harmful Algal Blooms (HABs)

Some phytoplankton taxa occur in Talbingo Reservoir but not in Tantangara Reservoir, including the HAB *Dolichospermum circinale*. Given the large volumes of water that would be transferred it is predicted assemblages of phytoplankton could become more similar in each reservoir, with an increase in HAB taxa from one taxon in each reservoir to two in each. For the introduction of HAB taxa to have an impact, volumes of HAB taxa would have to increase well above levels historically identified in either reservoir which is considered unlikely given the lack of HABs detected in sampling in both reservoirs over the last 20 years. Non-threatened native species present in the reservoir (mountain galaxias and Riek’s crayfish) would potentially be at risk. It is possible that HAB taxa could be transferred and for this to lead to a HAB at concentrations with the potential to impact biota within the reservoir. If an impact were to occur, it would not be expected to threaten the entire population within the reservoir (and catchment streams) and recovery would be likely to occur following the bloom. This leads to an assessment of risk of low.

The transfer of phytoplankton from Talbingo Reservoir to Tantangara Reservoir could also result in the alteration of the phytoplankton assemblage. Given the large volumes of water involved, transfer between reservoirs could result in changes to phytoplankton assemblages that make them more similar within both reservoirs. Changes in the phytoplankton assemblage may affect other aquatic biota that consume or are otherwise associated with phytoplankton, although this is possible. The likelihood of an impact to the existing assemblage is possible, consequence is minor leading to a risk assessment of moderate (**Table 7-6**).

Proliferation of Non-native Aquatic Plants

Elodea was recorded in both reservoirs during surveys for the project. It was abundant and widespread in Talbingo Reservoir, but observed at only one location on one occasion in Tantangara Reservoir. Given its abundance in Talbingo Reservoir, it is possible that pieces may be transferred to Tantangara Reservoir.

The transfer of water from Talbingo Reservoir may increase the abundance of *Elodea* in Tantangara Reservoir, although conditions in Tantangara Reservoir may be less suitable for *Elodea* than in Talbingo Reservoir. *Elodea* grows from rhizomes anchored in fine sediment and can form dense mats just below the surface of a water body. The large fluctuations in water levels that can currently occur, and that would be expected during Snowy 2.0, may prevent the establishment of this pest plant there due to periodic exposure and desiccation. The substratum in Tantangara Reservoir also consists predominantly of bare rock and unconsolidated sand and gravel that would be less suitable for growth of *Elodea.*

Elodea has potential to affect native vegetation by reducing light available for other aquatic plants. By itself, potential changes in the abundance of *Elodea* are not expected to have substantial consequences for aquatic fauna in Tantangara Reservoir (primarily *Galaxias* spp., Reik's crayfish, salmonids and introduced common yabby) and risk to threatened and non-threatened native species is assessed as low (**Table 7-6**).

7.2.4.4 Catchments

Phytoplankton, including Harmful Algal Blooms (HABs)

Phytoplankton transferred from Talbingo Reservoir to Tantangara Reservoir may be transferred to Lake Eucumbene and from there to other components of the Snowy Hydro Scheme (including Tumut Pond Reservoir and Geehi Reservoir). This could increase the chance of HABs occurring there, particularly if taxa transferred from Talbingo Reservoir were not present in these areas prior to Snowy 2.0. For this to have an impact, counts of HAB would need to increase well above levels historically identified in any Snowy Hydro reservoir which is considered unlikely. It is also possible that if HABs did occur in Talbingo Reservoir or Tantangara Reservoir that water quality could be affected in downstream and connected watercourses if water with low dissolved oxygen (DO) and or containing algal toxins associated with HABs is released or transferred.

In general, HABs would be expected to be less likely to occur in watercourses given that flowing water environments would be less suitable for the proliferation of phytoplankton. However, they do occur at least in slower flowing lowland rivers.

Proliferation of Non-native Aquatic Plants

There is potential for *Elodea*, if not already present in Lake Eucumbene, to be transferred there via the Murrumbidgee-Eucumbene tunnel. Given the very fine mesh screens proposed to be installed to prevent fish movement through the Tunnel and the ROW, the likelihood of transfer of plant material to Eucumbene or the mid-Murrumbidgee River would be rare

7.2.4.5 Potential Impacts on Aquatic Habitat and Biota

As is the case with Talbingo Reservoir and Tantangara Reservoir, it is difficult to predict how transfer of phytoplankton to Lake Eucumbene and to other waterbodies connected via the Snowy 2.0 would alter the probability of HABs occurring here. If potential HAB forming phytoplankton are transferred to new areas, then the chance of HABs occurring there may increase. However, if the background rate of occurrence of HABs in these areas is very low (due to, for example, naturally low background concentrations of nutrients), then there is likely to be a small or even negligible increased chance of HABs forming regardless of the transfer of potential HAB forming phytoplankton.

There is potential for water quality to be affected in catchments downstream of any HABs that may occur in Talbingo Reservoir, Tantangara Reservoir and other waterbodies. This could be associated with the release of water with low DO or containing algal toxins. The extent and magnitude of associated impacts to aquatic biota would depend on the severity of changes in water quality in upstream waterbodies and the volume of water released. These are assessed in **Section 7.2.4.5** alongside assessment of the change in probability of HABs occurring during Snowy 2.0.

If transferred to Lake Eucumbene, *Elodea* has potential to become established there. This could result in alteration of aquatic habitat (for example colonisation of bare sediment), the displacement of native aquatic plants and associated effects on aquatic fauna. Given the fish assemblage in Lake Eucumbene appears to consist primarily of non-native species (salmonids, wild goldfish and oriental weatherloach), negative effects on native fish species due to the potential transfer and establishment of *Elodea* in Lake Eucumbene (if it is currently absent) are unlikely. There is also potential for *Elodea* to establish in the Mid-Murrumbidgee River downstream of Tantangara Reservoir, if it is not present here currently. Although given this is a flowing watercourse it would be much less likely to establish substantial beds here compared with reservoir and lake environments.

7.2.4.6 Mitigation Measures and Residual Risks

The many uncertainties surrounding prediction of the occurrence of HABs hinders the assessment of increased chance of an HAB due to transfer of phytoplankton between the reservoirs. Transfers of water could lead to the introduction of additional HAB taxa although the likelihood of this leading to a HAB may be very low given the apparently low natural nutrient concentrations in the reservoirs. Similarly, assessment of the risk associated with changes in the phytoplankton assemblage cannot be considered in isolation of changes in other components of aquatic biota and these are assessed cumulatively in **Section 8**. Given the apparent unsuitability of Tantangara Reservoir for the establishment of *Elodea*, and given no threatened species are present in the reservoir, this is considered a low risk to aquatic habitats and biota here (**Table 7-6**).

In terms of mitigative measures to control the impacting pathways described in **Section 7.2.4.1** there are no direct practical methods for mitigating the transfer of phytoplankton between reservoirs or reducing the likelihood of occurrence. As such, measures to minimise, monitor and manage potential risks would be implemented. Surveillance monitoring for phytoplankton blooms and rapid response to fish kills associated with blooms would aid in the management of phytoplankton transfer between catchments.

Mitigation measures outlined in **Table 7-5** would be implemented to control risks from phytoplankton transfer between reservoirs.

Table 7-5 Mitigation measures to control risks from phytoplankton transfer between reservoirs.

Mitigation Code	Description
AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
AE19	The surveillance and management of HABs will be in accordance with existing Snowy Hydro procedures

It is considered that the residual risk associated with the transfer of plant and phytoplankton as a result of Snowy 2.0 operations would range between low and moderate (**Table 7-6**).

Table 7-6 Qualitative risk assessment of likelihood and consequences of transfer of plant and phytoplankton. L=Likelihood of occurrence; C = Consequence of occurrence. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Indirect - plant and phytoplankton	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Minor	Mod	Possible	Minor	Mod

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
transfer leading to HABs		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Possible	Minor	Mod
		Native Aquatic Species	Possible	Minor	Mod	Possible	Minor	Mod
		Salmonids	Possible	Minor	N/A	Possible	Minor	N/A
		Phytoplankton Assemblages	Possible	Minor	Mod	Possible	Minor	Mod
	Tantangara Reservoir	Threatened Aquatic Species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Unlikely	Minor	Low	Unlikely	Minor	Low
		Salmonids	Unlikely	Minor	N/A	Unlikely	Minor	N/A
		Phytoplankton Assemblages	Possible	Minor	Mod	Possible	Minor	Mod
	Yarrangobilly River	Threatened aquatic species - Trout cod	Rare	Minor	Low	Rare	Minor	Low
		Threatened aquatic species - Murray crayfish	Rare	Minor	Low	Rare	Minor	Low
		Native Aquatic Species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	Rare	Insig	N/A	Rare	Insig	N/A
		Phytoplankton Assemblages	Rare	Minor	Low	Rare	Minor	Low
	Upper Murrumbidgee River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	Rare	Minor	N/A	Rare	Minor	N/A
		Phytoplankton Assemblages	Rare	Minor	Low	Unlikely	Minor	Low
	Mid Murrumbidgee River	Threatened aquatic species - Macquarie perch	Unlikely	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Murray Cod	Unlikely	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Trout cod	Unlikely	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Southern pygmy perch	Unlikely	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Unlikely	Minor	Low	Unlikely	Minor	Low
		Native Aquatic Species	Unlikely	Minor	Low	Unlikely	Minor	Low
		Salmonids	Unlikely	Minor	N/A	Unlikely	Minor	NA
		Phytoplankton Assemblages	Unlikely	Minor	Low	Unlikely	Minor	Low
	Lake Eucumbene	Threatened Aquatic Species	NA	NA	N/A	NA	NA	N/A
		Native Aquatic Species	Unlikely	Minor	Low	Unlikely	Minor	Low
		Salmonids	Unlikely	Minor	N/A	Unlikely	Minor	N/A
		Phytoplankton Assemblages	Unlikely	Minor	Low	Unlikely	Minor	Low
Indirect - proliferatoin of non-native aquatic plants	Talbingo Reservoir	Threatened aquatic species - Trout cod	N/A	N/A	N/A	N/A	N/A	N/A
		Threatened aquatic species - Murray crayfish	N/A	N/A	N/A	N/A	N/A	N/A

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
		Native Aquatic Species	N/A	N/A	N/A	N/A	N/A	N/A
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Phytoplankton Assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened Aquatic Species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Possible	Insig	Low	Possible	Insig	Low
		Salmonids	Unlikely	Insig	N/A	Unlikely	Insig	N/A
		Phytoplankton Assemblages	Possible	Insig	Low	Possible	Insig	Low
	Upper Murrumbidgee River	Threatened Aquatic Species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Rare	Minor	Low	Rare	Minor	Mod
		Salmonids	Rare	Minor	N/A	Rare	Minor	N/A
		Phytoplankton Assemblages	Rare	Insig	Low	Rare	Insig	Low
	Mid Murrumbidgee River	Threatened aquatic species - Macquarie perch	Rare	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Murray Cod	Rare	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Trout cod	Rare	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Southern pygmy perch	Rare	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Rare	Minor	Low	Unlikely	Minor	Low
		Native Aquatic Species	Rare	Minor	Low	Unlikely	Minor	Low
		Salmonids	Rare	Minor	N/A	Unlikely	Minor	N/A
		Phytoplankton Assemblages	Rare	Minor	Low	Unlikely	Minor	Low
	Lake Eucumbene	Threatened Aquatic Species	NA	NA	N/A	NA	NA	N/A
		Native Aquatic Species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	Rare	Minor	N/A	Rare	Minor	N/A
		Phytoplankton Assemblages	Rare	Minor	Low	Rare	Minor	Low

7.2.5 Fish Disease Transfer

7.2.5.1 Description of Impacting Processes

The assessment of impacts due to fish disease focuses on the EHNV as discussed in **Section 5.4.9** and **Section 5.3.9**. The focus of this assessment is on the impact of EHNV on native fishes. Impacts to trout and redfin perch are considered in terms of recreational impacts associated with those species by other specialists as part of the social impact assessment (Appendix X.2-Recreational Users Study, EMM, 2019a). Other diseases/parasites are likely to pose negligible risk to key receptors and are not considered further.

The assessment of risk associated with EHNV is based on expert advice on EHNV prepared on behalf of Snowy Hydro by experts at the University of Sydney (Hick, et al., 2019). The impacting process with respect to EHNV, should it occur would be potential infection of fish with the virus, leading to death and, as a secondary impact, deterioration of water quality due to decomposition of dead fish. Fish may carry the virus without obvious signs until an outbreak occurs leading to mass mortality. Although the environmental triggers that may cause an outbreak are unclear, current knowledge suggests that it is unlikely that the project itself would directly cause an outbreak of EHNV, but it could facilitate indirect causation by transfer among reservoirs, rivers and streams that become connected by Snowy 2.0. Outbreaks of EHNV are not common in the study area and the frequency and virulence of outbreaks may be declining. The last known outbreak in NSW occurred in Blowering Reservoir in 2009 (Becker et al., 2013). It is also likely that EHNV persists in places it once occurred (Becker et al., 2013).

7.2.5.2 Talbingo Reservoir

There is no recorded incidence of Talbingo Reservoir being affected by an outbreak of EHNV, despite having populations of redfin perch and rainbow trout, the latter being replenished by stocking from trout hatcheries. Of importance was the apparent fact that there was no outbreak of EHNV in Talbingo Reservoir at the time of the outbreak in Blowering Dam. Testing undertaken as part of this study also did not detect EHNV within water, or redfin perch present within Talbingo Reservoir, although the sample size was not sufficient to have high confidence in the result (Hick et al 2019).

Other species known or inferred to be susceptible to EHNV (at least in a laboratory setting) are eastern gambusia, mountain galaxias and Macquarie perch (Becker, et al., 2013). Climbing galaxias have also been detected in the Yarrangobilly catchment; their susceptibility to EHNV is unknown but considered possible. It is noted also that all outbreaks of EHNV have involved redfin perch, and that there are no known cases of infection of native species of fish in the wild.

Irrespective of Snowy 2.0, there is a risk that there could be an outbreak of EHNV in Talbingo Reservoir due to the presence of redfin perch in the reservoir. According to Hick et al. (2019) redfin perch are the most susceptible species in the study area and would tend to amplify the risk merely by their presence in a waterbody. Redfin perch that are infected but subclinical (i.e. showing no signs of infection) would attract a greater risk. In terms of risk of potential for infection an outbreak of EHNV would have a severe effect on redfin perch; a small, if not minor impact on rainbow trout, most likely among juveniles; and an unknown effect on eastern gambusia. Given the very likely small populations of trout cod, mountain galaxias and climbing galaxias in Talbingo Reservoir, potential impacts are assessed to be Low.

The risk assessment for Talbingo Reservoir in terms of Snowy 2.0 and its effect on key receptors of concern (**Table 7-8**) is based on the potential for redfin perch to become established in Tantangara Reservoir, followed by an outbreak of EHNV in those redfin perch within Tantangara Reservoir, some of which are then transferred back into Talbingo Reservoir. Based on the receptors present, assessment of the risk of EHNV outbreak within Talbingo Reservoir is low (**Table 7-8**). There is no direct mitigation available for the potential EHNV outbreaks.

7.2.5.3 Tantangara Reservoir

No redfin perch currently occur in Tantangara Reservoir and the populations of rainbow and brown trout there are self-sustaining (i.e. not stocked). Therefore, currently there are no known sources/vectors for transfer and outbreak of EHNV into Tantangara Reservoir, other than transfer by birds consuming fish, or illegal/accidental transfer of live or dead redfin perch, or of water, by humans. It is not known, however, if subclinical infection by EHNV occurs within Tantangara Reservoir (e.g. in rainbow trout - Hick et al. 2019). Notwithstanding, the transfer of water between Talbingo and Tantangara reservoirs under Snowy 2.0, would provide a direct conduit for fish (if infected) and any waterborne virus between the two reservoirs.

Of particular importance, redfin perch are predicted to be capable of surviving the transfer into Tantangara Reservoir and hence would be a potential vector for EHNV, should they become infected in Talbingo Reservoir. In any case, a fish that died during transfer could still act as a vector for transport of the virus, if infected. Note that even in the absence of an outbreak of the virus causing a fish kill in Talbingo Reservoir, redfin carrying the disease (subclinical, i.e. showing no outward signs of infection) could be transferred via the pipeline, potentially leading to a future outbreak of EHNV in Tantangara Reservoir sometime after transfer. Additionally, rainbow trout, gambusia and climbing galaxias, water and passive organic material may be transferred between reservoirs and hence be vectors.

Transfer of EHNV into Tantangara Reservoir could lead to infection of rainbow trout, which could impair the self-sustaining population there. As noted by Hick et al. (2019), fish may seek refuge from or treatment for EHNV by moving into cooler, deeper waters.

Over the long term operation of Snowy 2.0, there is potential that redfin perch would be transferred into Tantangara Reservoir from Talbingo Reservoir. A precautionary approach assumes that a proportion of redfin perch being transferred may be infected with EHNV (although there is no evidence that this is currently the case) and/or that redfin perch transferred to Tantangara Reservoir would amplify the risk of becoming infected by EHNV (Hick, et al., 2019). On this basis, there is a possible likelihood of transfer of EHNV, albeit at least in a subclinical form. The most abundant fish species within Tantangara Reservoir are brown and rainbow trout. Brown trout are not known for susceptibility to EHNV but rainbow trout are, at least in controlled farmed and laboratory settings, and therefore would be considered to be at risk. A fish kill of rainbow trout or redfin perch would affect the populations of either species and may have secondary impacts on water quality.

Based on the receptors present, assessment of the risk of EHNV outbreak within Tantangara Reservoir is considered to be moderate (**Table 7-8**).

7.2.5.4 Catchments

Secondary transfer of EHNV downstream from Talbingo Reservoir can occur at present independently of the proposed Snowy 2.0 and hence the impact of EHNV in fish originating in Talbingo Reservoir would be similar regardless of Snowy 2.0. If an outbreak of the virus occurred in Tantangara Reservoir (or if, somehow, fish in Tantangara Reservoir became infected with EHNV) and infected fish were then transferred into Talbingo Reservoir (as noted above), the virus may then travel further downstream and potentially into Jounama Pondage, Blowering Reservoir and Tumut and Murrumbidgee rivers. This is considered an unlikely outcome.

Apart from transfer downstream back into Talbingo Reservoir, there are three other potential secondary pathways for EHNV from Tantangara Reservoir:

> Yarrangobilly River. The occurrence of EHNV here would be due to active movement of infected fish upstream from the Snowy 2.0 outlet or by birds (or potentially by anglers disposing of infected fish). Given that the only way that Snowy 2.0 could facilitate an infection in fish in Talbingo Reservoir is if infected fish were transferred from Tantangara Reservoir, the likelihood of transfer into the Yarrangobilly River is considered to be Unlikely. The consequence for threatened native species (e.g. trout cod) is Moderate with an overall risk of Moderate (**Table 7-8**). The risk for non-threatened native species is considered to be the same. The likelihood of infection of rainbow trout in the Yarrangobilly River is unlikely, however, the consequence is less because rainbow trout are stocked into streams entering Talbingo Reservoir (i.e. populations are replenished by stocking).

> Upper Murrumbidgee River. Transfer upstream from Tantangara Reservoir could extend into the headwaters of the Murrumbidgee River and tributaries such as Tantangara Creek and Gooandra Creek; and into Kelly's Plain Creek; Nungar Creek; and Mosquito Creek. Because these streams flow into Tantangara Reservoir, EHNV could be transferred only within fish swimming upstream (and not in the water or passive organic matter) and by birds consuming infected fish and then flying upstream. Infected fish moving upstream could include trout, gambusia, redfin perch and climbing galaxias. This upstream penetration could lead to infection of existing trout populations (including trout spawning areas). Additionally, stocky galaxias are present in Tantangara Creek but isolated from other fish and so would likely be at risk only if fish-eating birds entered the catchment after feeding on infected fish or infected climbing galaxias penetrate into their habitat. The likelihood of complete extinction of this population as a result of transfer and subsequent infection with EHN is considered rare without controls and even less likely (i.e. 'rare') following the installation of the barrier proposed to prevent climbing galaxias incursion. It is not known whether stocky galaxias are susceptible to EHNV, but the consequence is considered potentially catastrophic for the species, given its extremely limited distribution. This leads to a high risk. Mitigation using a barrier to prevent movement of climbing galaxias reduces likelihood to rare and residual risk to moderate (**Table 7-8**).

> Middle Murrumbidgee (downstream of Tantangara Reservoir to the ACT border). If EHNV were to become established in Tantangara Reservoir, it may be transferred downstream by infected fish (redfin perch, rainbow trout or climbing galaxias), the water itself or birds, although transfer of fish is not predicted due to the proposed installation of a fish barrier to prevent this. The position of this section of river differs from the other streams considered because infection could come from an upstream source rather than downstream. A precautionary approach warrants a conclusion of a possible occurrence of EHNV within native species (threatened or non-threatened) during the life of the project but is considered unlikely following installation of the fish barrier which would be expected to reduce, but not eliminate, the risk of EHNV being transferred in the event of an outbreak of EHNV in Tantangara Reservoir. The Mid Murrumbidgee supports populations of Macquarie perch, trout cod, Murray cod, Murray crayfish and a predicted population of southern pygmy perch (NSW DPI, 2016a). On this basis consequence is determined as moderate and the risk as moderate (**Table 7-8**).

  Salmonids would be considered likely to be subject to EHNV infection, should one occur, however, this would not lead to the loss of a population due to the typically low mortality rates in this species. The consequence is therefore predicted as minor.

> Upper Eucumbene (Tantangara Reservoir - Lake Eucumbene tunnel). Transfer of EHNV via the Tantangara-Eucumbene tunnel could pose a potential risk to Lake Eucumbene, Lake Jindabyne and the associated Endangered Ecological Community (EEC). The risk is considered possible in the event that Redfin establish in these catchments but is considered unlikely in proximal catchments such as

Eucumbene and rare in areas beynd this due to the proposed fish barrier that would prevent transfer of fish that could potentially carry the virus. Two threatened species are predicted to occur within this catchment, southern pygmy perch and river blackfish, both downstream of the dam wall at Lake Jindabyne. river blackfish are also predicted to occur within the Lake Jindabyne catchment upstream of the dam (NSW DPI, 2016a). Both species have other populations outside these catchments. Southern pygmy perch has been shown in laboratory settings to be resistant to EHNV and the susceptibility of river blackfish is unknown. The likelihood of infection by EHNV on river blackfish as a result of Snowy 2.0 is considered to be (extremely) rare. Given the fact that redfin perch would not be present to amplify the disease, it would not be expected that an outbreak would lead to permanent changes to the populations of any fish in these reservoirs. The overall risk is considered low (**Table 7-8**). Salmonids are present throughout this catchment, hence infection with EHNV in rainbow trout (at least) would be possible as a result of the transfer of infection via the tunnel, but unlikely following mitigation measures. Given the large number of locations where trout are present, it is likely that an infection would lead only to temporary adverse changes with recovery either via natural processes or stocking.

7.2.5.5 Mitigation Measures and Residual Risks

There is a range of potential mitigation measures that could be implemented to reduce the risk of impacts associated with EHNV. All these measures rely very heavily on having a rigorous program of surveillance monitoring that would be the basis for triggering management responses. Most of these can be initiated only after EHNV has been discovered in a population (either occurring within asymptomatic fish or following an outbreak of the virus leading to mortality). Two broad categories of mitigation are containment/establishment of barriers to movement and implementation of surveillance which would be linked to response in the event of an outbreak of EHNV, as evidenced by fish kill. In considering the practicality of these options, the following mitigation measures in **Table 7-7** will be implemented to minimise and manage potential impacts from EHNV.

Table 7-7 Mitigation measures to minimise and manage potential impacts from EHNV.

Mitigation Code	Description
AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
AE04	A Weed, Pest and Pathogen Management Plan would be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.

Based on the assessment provided above the residual effects of fish disease transfer within the study area would be 'low' in Talbingo Reservoir and 'low to moderate' in Tantangara Reservoir and other catchments currently connected with Tantangara Reservoir (**Table 7-8**).

Table 7-8 Qualitative risk assessment of likelihood and consequences of transfer of outbreak of EHNV disease as a result of Snowy 2.0 before and after proposed mitigation. L=Likelihood of occurrence; C = Consequence of occurrence. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Indirect - fish disease transfer leading to mortality	Talbingo Reservoir	Threatened aquatic species - Trout cod	Unlikely	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Rare	Minor	Low	Rare	Minor	Low
		Native Aquatic Species	Unlikely	Minor	Low	Unlikely	Minor	Low
		Salmonids	Unlikely	Minor	N/A	Unlikely	Minor	N/A
	Tantangara Reservoir	Threatened Aquatic Species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Possible	Minor	Mod	Possible	Minor	Mod
		Salmonids	Likely	Minor	N/A	Likely	Minor	N/A
	Yarrangobilly River	Threatened aquatic species - Trout cod	Unlikely	Minor	Low	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Rare	Minor	Low	Rare	Minor	Low
		Native Aquatic Species	Unlikely	Minor	Low	Unlikely	Minor	Low
		Salmonids	Unlikely	Minor	N/A	Unlikely	Minor	N/A
	Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Rare	Catas	Mod	Rare	Catas	Mod
		Native Aquatic Species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Murrumbidgee River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Possible	Minor	Mod	Possible	Minor	Mod
		Salmonids	Likely	Mod	N/A	Likely	Mod	N/A
	Mid Murrumbidgee River	Threatened aquatic species - Macquarie perch	Possible	Minor	Mod	Unlikely	Minor	Low
		Threatened aquatic species - Murray Cod	Possible	Minor	Mod	Unlikely	Minor	Low
		Threatened aquatic species - Trout cod	Possible	Minor	Mod	Unlikely	Minor	Low
		Threatened aquatic species - Southern pygmy perch	Possible	Minor	Mod	Unlikely	Minor	Low
		Threatened aquatic species - Murray crayfish	Rare	Minor	Low	Rare	Minor	Low
		Native Aquatic Species	Possible	Mod	Mod	Unlikely	Mod	Mod
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A
	Lake Eucumbene	Threatened Aquatic Species	N/A	N/A	N/A	N/A	N/A	N/A
		Native Aquatic Species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A

7.3 Maintenance and Decommissioning of Infrastructure and Utilities

7.3.1 Description of Impacting Processes

The construction phase for Snowy 2.0 Main Works is expected to be over a six year period. On completion of the Main Works, temporary construction elements such as construction compounds, accommodation camps and temporary access roads will be decommissioned and subject to ongoing rehabilitation and revegetation. This may involve for example, removing infrastructure, hardstands, plant, equipment, buildings and other structures and all contaminated and hazardous materials associated with those sites. As a large proportion of Snowy 2.0 Main Works are within the boundaries of the KNP, Snowy Hydro would liaise closely with the NPWS to determine the extent of decommissioning of temporary construction facilities. The approach to be taken would aim to maintain the values of the KNP.

Elements of surface works and infrastructure that are likely to be decommissioned and of which their decommissioning has potential to impact on aquatic habitats and biota include:

> Temporary access roads including:
  - Exploratory Camp Road;
  - Ravine Bay Road; and
  - Tantangara Camp Road.
> Accommodation camps;
> Construction portals;
> Construction staging compounds; and
> Wastewater and wastewater management infrastructure (treatment plants and pipelines).

These areas are generally located near intakes within Talbingo Reservoir and Tantangara Reservoir and Lobs Hole and within the Plateau region of the project area.

Once operational, maintenance activities required for Snowy 2.0 would be integrated with the maintenance of the existing Snowy Scheme. Elements of these maintenance activities that have potential to impact on aquatic biota and habitats include:

> Maintenance of access roads (vegetation clearing, pavement works, snow clearing);
> Maintenance of electricity infrastructure (cables, cable yard, cable tunnel); and
> Dewatering of the headrace and tailrace tunnel (estimated at once every 15 to 50 years, or as required).

There are several direct and indirect pathways and mechanisms via which decommissioning and maintenance activities have potential to impact on aquatic habitats and associated flora and fauna within the project area. These include:

> Direct - removal/modification of habitat and associated biota at infrastructure locations;
> Indirect – changes to water quality due to tunnel dewatering (point source);
> Indirect - changes to water quality from surface run-off (diffuse); and
> Indirect – spread of aquatic weeds and pests.

Potential impact pathways will be broadly managed via a Rehabilitation Plan. This would address the general ongoing maintenance requirements for all of the landscape and rehabilitation work areas. Impacts of decommissioning or maintenance that require surface works will also be controlled via the methodologies outlined in the ESCP.

7.3.2 Impacts on Habitats and Biota

7.3.2.1 Direct - removal/modification of habitat and associated biota at infrastructure locations

Works potentially impacting on aquatic biota and habitat include the decommissioning of access roads, accommodation camps and construction compounds which transect several small unnamed and ephemeral watercourses. Temporary wastewater treatment facilities and outlets will also be located in the vicinity of watercourses and reservoirs.

Temporary access roads are generally aligned to minimise direct impacts to aquatic habitat and biodiversity and where possible, would include exclusion buffer either side of any watercourses (except for where bridges or other crossing structures are constructed). Direct impacts to riparian vegetation and associated biota would therefore have already occurred during the construction process. The Rehabilitation Plan would ensure that any affected watercourses are restored to be hydraulically and geomorphologically stable and the aquatic ecology and riparian vegetation restored to the same or better condition than prior to project approval, whever feasible. Provided that appropriate waste management and erosion and sediment controls are adopted (as per the WMP and ESCP) then risks of contaminants entering watercourses would not be expected during decommissioning works. Similar principles would apply to the maintenance of permanent roads and cable access routes (which may transect several watercourses) and therefore direct impacts to biota and habitat not already disturbed through construction activities would be minimal.

Based on the receptors present, assessment of unmitigated risk levels from the direct removal/modification of habitat during the projects operational phase would range from low to moderate. The residual risk, following the implementation of the mitigation measures identified in **Section 7.3.5** would be low (**Table 7-10**).

7.3.2.2 Indirect - changes to water quality due to tunnel dewatering and station drainage

During operation, the tailrace tunnel would occasionally need to be dewatered to enable maintenance access. To achieve this, it is expected that approximately 550 ML of water would be drained from the tunnel at a maximum rate of 170 ML/day (2m^3/sec) over a period of up to seven days. The water will be discharged into a drainage system that would convey the water to the Yarrangobilly River. The drainage system would be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the discharge rate and duration.

No impacts to the Yarrangobilly River are expected as:

- the discharge rate is well within the natural flow regime of the river; and
- the water contained in the tailrace to be discharged would have originated from either Tantangara or Talbingo reservoirs, which have similar water quality to the Yarrangobilly River

The station would be designed with a drainage system to capture and release water that collects within the station and dry tunnels. The system would be designed to manage the potential for contamination and water will be released in accordance with relevant approved procedures and licences (see Water Management Plan).

7.3.2.3 Indirect - changes to water quality from surface run-off (diffuse)

Indirect impacts to water quality could occur where earthworks and disturbance of surface sediments is removed as part of decommissioning and demolition of construction compounds, water treatment infrastructure and accommodation camps. This level of disturbance is likely to be minimal compared with the construction related impacts that may have required vegetation clearing. During the construction phase, contaminants such as hydrocarbons may have accumulated on road and hardstand surfaces (particularly in construction staging areas where heavy plant and equipment were used), hence there is a pathway for contaminants to enter waterways following further disturbance during demolition and decommissioning particularly after rainfall. Contaminated soils presenting constraints to final land use will be identified and remediated or removed from the areas to be rehabilitated or appropriately managed (in accordance with legislation). Standard erosion and sediment controls as outlined in the ESCP would also be adopted to manage impacts of diffuse surface run-off on receiving watercourses. Temporary roads and areas of surface works disturbance will be rehabilitated and re-vegetated to match or enhance their pre-construction condition.

Similar measures would be adopted during any maintenance activities involving disturbances to earthworks potentially draining into watercourses. With all these controls in place as outlined in the ESCP and WMP any impacts to watercourses would be considered unlikely and minor in nature. Based on the receptors present, assessment of unmitigated risk levels from indirect changes to water quality (diffuse sources) during the projects operational phase would be low. The residual risk, following the implementation of the mitigation measures identified in **Section 7.3.5** would remain low (**Table 7-10**).

7.3.2.4 Indirect – spread of aquatic weeds and pest fish

Heavy plant, vehicles operating in and around waterways during decommissioning and maintenance works have potential to act as vectors for a range of aquatic weeds and pest fish if not properly managed. *Elodea* occurs in Talbingo and Tantangara reservoirs and may occur in some creeks and streams throughout the project area. As aquatic plants like *Elodea* grow and spread via fragmentation these are easily transported in water and may be transferred among water courses by vectors such as work barges or heavy plant. Species of pest fish including redfin perch, eastern gambusia and goldfish have also been recorded in watercourses within the project area and their eggs have the potential to be spread if they come in contact with vectors. Measures would therefore be adopted to minimise this risk in accordance with the Weed, Pest and Pathogen Management Plan during decommissioning and with Standard Snowy Hydro Procedures during operation. Following conclusion of construction activities, the risk would be expected to be broadly similar to the existing risks associated with the operation of the current snowy scheme. Based on the receptors present, assessment of unmitigated risk levels of spreading aquatic weeds and pest fish during the projects operational phase would range from low to high. The residual risk, following the implementation of the mitigation measures identified in **Section 7.3.5** would be low to moderate (**Table 7-10**).

7.3.3 Impacts on KFH, Threatened Species and EECs

Decommissioning of the temporary infrastructure identified in **Section 7.3.1** is not likely to directly affect watercourses potentially providing habitat for threatened species. In the absence of mitigative controls, the cumulative effects of diffuse surface water run-off could affect the Upper Murrumbidgee Catchment where communications routes transect Tantangara Creek (below where the stocky galaxias occurs). The aquatic ecosystem of the Eucumbene River (Lake Eucumbene Catchment) is also considered part of the Snowy River EEC (**Section 5.6.2**) which has the potential to be indirectly impacted by uncontrolled surface run-off to the Eucumbene River. These diffuse impacts would be considered minimal in comparison to the construction works which would have occurred previously at these locations and would not be expected to significantly impact populations of a threatened species or EEC.

7.3.4 Key Threatening Processes

Decommissioning and maintenance would have potential to facilitate the following KTPs if not appropriate controls were not in place:

> Degradation or native riparian vegetation along New South Wales water courses (FM Act);

> Introduction of fish to waters within a river catchment outside their natural range (FM Act); and

> Loss and degradation or native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act).

The area likely to be the maintenance and decommissioning activities will be very small relative to the total area of shoreline and aquatic habitats throughout the study area.

7.3.5 Mitigation Measures and Residual Risks

Mitigation measures outlined in **Table 7-9** would be implemented to control operational risks associated with decommissioning and maintenance activities.

Table 7-9 Mitigation measures to control operational risks associated with decommissioning and maintenance activities.

Mitigation Code	Description
AE11	Rehabilitation of temporary roads and areas used for construction will occur in accordance with the Rehabilitation Plan
AE20	Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure decommissioning to manage impacts of diffuse surface run-off on receiving watercourses. Ongoing road maintenance would be managed in accordance with existing Snowy Hydro procedures.
AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas

Mitigation Code	Description
	– notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
AE11	Rehabilitation of temporary roads and areas used for construction would occur in accordance with the Rehabilitation Plan
AE21	Watercourses subject to disturbance from construction and / or decommissioning would be rehabilitated to ensure that they are hydraulically and geomorphologically stable
AE04	A Weed, Pest and Pathogen Management Plan would be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.
AE22	Water released during tunnel and station dewatering for operations would be undertaken in accordance with operational procedures and management plans and in accordance with relevant licences

Provided that the mitigation measures outlined above are implemented then the residual risk levels of decommissioning and maintenance on aquatic receptors would be ‘low’ to ‘moderate’ (**Table 7-10**).

Table 7-10 Qualitative risk assessment of likelihood and consequences of decommissioning and maintenance before and after proposed mitigation. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic. Mod=Moderate, Insig=Insignificant, Catas=Catastrophic

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
Direct - removal/modification of habitat and associated biota	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Yarrangobilly River	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Minor	Mod	Unlikely	Insig	Low

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Murrumbidgee River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Rare	Minor	Low	Rare	Minor	Low
		Native aquatic species	Rare	Minor	Low	Rare	Minor	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Possibl e	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
Indirect - changes to water quality due to tunnel dewatering (Point source)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Minor	Mod	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Minor	Mod	Unlikely	Insig	Low
		Salmonids	Possible	Minor	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Minor	Mod	Unlikely	Insig	Low
		Salmonids	Possible	Minor	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
Indirect - changes to water quality from diffuse surface run-off (Diffuse)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Yarrangobilly River	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low

Potential Impact	Catchment	Receptor	Before Mitigation L	Before Mitigation C	Before Mitigation Risk	After Mitigation L	After Mitigation C	Residual Risk
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Upper Murrumbidgee River	Threatened aquatic species - Macquarie perch (low)	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insign	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	Possible	Insig	Low	Unlikely	Insig	Low
Indirect – spread of aquatic weeds and pest fish	Talbingo Reservoir	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Tantangara Reservoir	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Yarrangobilly River	Threatened aquatic species - Trout cod	Possible	Insig	Low	Unlikely	Insig	Low
		Threatened aquatic species - Murray crayfish	Possible	Insig	Low	Unlikely	Insig	Low
		Native aquatic species	Possible	Insig	Low	Unlikely	Insig	Low
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Murrumbidgee River	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	Possible	Insig	N/A	Unlikely	Insig	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A
	Lake Eucumbene	Threatened aquatic species	N/A	N/A	N/A	N/A	N/A	N/A
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	Possible	Minor	N/A	Unlikely	Minor	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A

Potential Impact	Catchment	Receptor	Before Mitigation			After Mitigation		
			L	C	Risk	L	C	Residual Risk
	Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Possible	Major	High	Unlikely	Major	Mod
		Native aquatic species	Possible	Major	High	Unlikely	Major	Mod
		Salmonids	N/A	N/A	N/A	N/A	N/A	N/A
		Planktonic assemblages	N/A	N/A	N/A	N/A	N/A	N/A

8 Cumulative Impacts

All identified construction and operational related activities and associated impacts have potential to affect sensitive aquatic receptors in Talbingo Reservoir, Tantangara Reservoir and other catchments within the study area. Although the potential effects of the various project impacts have been considered separately, there are likely to be interactions among impacts associated with the project design that could reduce or magnify the intensity of a response or raise or lower the threshold of response. Moreover, there is also potential for cumulative effects between the project and external factors. Interactive effects of multiple impacts are poorly understood but given most of the impacts affect similar receptors within the study area and a worse case scenario has been assumed for each impact (ie mortality to biota), then cumulative impacts are considered unlikely to change the conclusions of this assessment. Cumulative impacts may lengthen the recovery time in some areas for some sensitive receptors but not to the extent that would change the stated conclusions.

9 Summary of Mitigation Measures and Residual Risks

9.1 Summary of Mitigation Measures

Throughout the impact assessment, a number of measures have been proposed that would aim to reduce or mitigate impacts on the aquatic environment within the study area that could potentially occur as part of Snowy 2.0 Main Works. Mitigation measures associated with each activity and impact are summarised in **Table 9-1**.

For the Main Works offsets would be applied to residual impacts to key values of KNP, including aquatic ecology. An outcomes based approach to dealing with the residual impacts of the project is proposed to be achieved by working cooperatively with the relevant stakeholders in particular, PDIE, NPWS, OEH and DPI Fisheries. Further detail about Snowy Hydro's offset strategy for Main Works can be found in the Snowy 2.0 Main Works EIS.

Table 9-1 Summary of mitigation measures proposed to address potential impacts of Snowy 2.0 Main Works on aquatic ecology

Phase	Activity	Mitigation Code	Description
Construction	Construction of intakes and dredging works	AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
		AE07	All dredging works would be closely monitored and carried out in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP)
		AE08	A silt curtain would be deployed to minimise the spread of turbid water/suspended solids beyond the footprint, where practicable.

Phase	Activity	Mitigation Code	Description
		AE09	Contaminated sediments and soils posing a risk to aquatic habitats would be managed in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP).
		AE06	Designated blast limits and other management measures to minimise impacts to aquatic ecology would be outlined in the Blast Management Plan.
	Edge push placement in reservoirs	AE08	A silt curtain would be deployed to minimise the spread of turbid water/suspended solids beyond the footprint, where practicable
		AE09	Contaminated sediments and soils posing a risk to aquatic habitats would be managed in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP).
		AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
	Surface infrastructure and utilities	AE10	Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure construction to manage impacts of diffuse surface run-off on receiving watercourses.
		AE11	Rehabilitation of temporary roads and areas used for construction would occur in accordance with the Rehabilitation Plan

Phase	Activity	Mitigation Code	Description
		AE02	Bridges or culverts would be designed and constructed in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge 2003), where practicable.
		AE03	Construction works within the channel of a permanent waterway with Type 1 or 2 key fish habitat would allow some flow to maintain fish passage at all times and be staged to minimise the total disturbance at any given time.
		AE12	Where possible, an exclusion buffer would be applied for road construction either side of a river except where bridges or other crossing structures are required.
		AE13	Procedures for the management of woody debris disturbed during construction of bridges or other waterway crossings would be outlined within the AqHMP.
		AE14	Where cable routes intersect permanent waterways containing Type 1 or 2 key fish habitat, construction will be carried out in a manner that does not obstruct flow and minimises habitat disturbance.
		AE15	Wastewater, including tunnel process water, will be treated and released in accordance with the measures specified in the Water Management Plan.
		AE16	Wastewater outlets would be designed and positioned to minimise the footprint of hard bank engineering and prevent bank scouring and erosion.
		AE04	A Weed, Pest and Pathogen Management Plan would be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.
		AE15	Wastewater, including tunnel process water, would be treated and released in accordance with the measures specified in the Water Management Plan
Operat ion	Transfer of water between Talbingo	AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries;

Phase	Activity	Mitigation Code	Description
	and Tantangara Reservoirs		• include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
		AE17	Install a fish barrier on Tantangara Creek designed to prevent upstream migration of climbing galaxias
		AE18	Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel
		AE19	The surveillance and management of HABs would be in accordance with existing Snowy Hydro procedures
	Maintenance and decommissioning of infrastructure and utilities	AE11	Rehabilitation of temporary roads and areas used for construction would occur in accordance with the Rehabilitation Plan
		AE20	Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure decommissioning to manage impacts of diffuse surface run-off on receiving watercourses. Ongoing road maintenance will be managed in accordance with existing Snowy Hydro procedures.
		AE01	An Aquatic Habitat Management Plan (AqHMP) would be prepared and implemented to guide management of impacts to aquatic habitat. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat;

Phase	Activity	Mitigation Code	Description
			– minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species; • include a program to restore and enhance the aquatic habitat of the approved disturbance area with the exception of intakes and channel areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.
		AE11	Rehabilitation of temporary roads and areas used for construction would occur in accordance with the Rehabilitation Plan
		AE21	Watercourses subject to disturbance from construction and / or decommissioning would be rehabilitated to ensure that they are hydraulically and geomorphologically stable
		AE09	Contaminated sediments and soils posing a risk to aquatic habitats would be managed in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP)
		AE04	A Weed, Pest and Pathogen Management Plan would be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan would: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.
		AE22	Water released during tunnel and station dewatering for operations would be undertaken in accordance with operational procedures and management plans and in accordance with relevant licences

9.2 Summary of Residual Risks

Table 9-2 summarises the residual risks from impacts of various activities and impacts on aquatic ecology within the study area as part of the Snowy 2.0 Main Works and operations following the implementation of mitigation measures outlined in **Table 9-1**. The classification of residual risks for each activity are as per that described in **Section 4.5**.

Table 9-2 Summary of residual risks for various impacts following mitigation measures proposed to be incorporated throughout the project. N/A=Not Applicable, Mod=Moderate, Ext=Extreme

Activity	Potential Impact	Catchment	Receptor	Residual Risk
Construction Phase				
Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
	Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
	Direct – noise and vibration from blasting	Talbingo Reservoir	Threatened aquatic species - Trout cod	Mod
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	Mod
	Indirect - changes to water quality (via sediment mobilisation during dredging)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
	Indirect - Dredging related noise	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
Edge push placement of excavated material	Loss/ modification of aquatic habitat due to smothering	Talbingo Reservoir	Threatened aquatic species-Trout cod	Low
			Threatened aquatic species-Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	N/A
			Salmonids	N/A
			Planktonic assemblages	N/A
	Displacement/ direct mortality of existing aquatic organisms	Talbingo Reservoir	Threatened aquatic species-Trout cod	Low
			Threatened aquatic species-Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
	Changes to water quality	Talbingo Reservoir	Threatened aquatic species-Trout cod	Mod
			Threatened aquatic species-Murray crayfish	Mod
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	Mod
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	N/A
			Salmonids	N/A
			Planktonic assemblages	N/A
Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Murrumbidgee River	Threatened aquatic species	N/A

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
	Direct – temporary obstruction to fish passage	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Murrumbidgee River	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
	Direct – changes to water quality from point source discharges (i.e. waste water outlets)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
	Indirect - changes to water quality from diffuse surface run-off	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Upper Murrumbidgee River	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
	Indirect – spread of aquatic weeds and pest fish	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Murrumbidgee River	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Mod
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
Tunnel excavation and groundwater drawdown	Reduction in the availability and connectivity of aquatic habitat	Upper Murrumbidgee River Catchment	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
		Lake Eucumbene Catchment	Native aquatic species	Mod
			Salmonids	N/A
			Snowy River EEC	Mod
		Yarrangobilly River Catchment	Native aquatic species	Mod
			Salmonids	N/A

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Threatened aquatic species – Murray crayfish	Mod
Operation Phase				
Transfer of water between Talbingo and Tantangara Reservoirs	Direct - Hydraulic entrainment and entrapment of biota	Talbingo Reservoir	Threatened aquatic species – trout cod	Low
			Threatened aquatic species – Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Mod
	Indirect - Impact of fish transfer on fish ecology	Tantangara Reservoir	Threatened aquatic species	N/A
			Other native aquatic species	Mod
			Salmonids	N/A
		Upper Murrumbidgee River Catchment (excluding Upper Tantangara Creek)	Native species - Mountain galaxias	High
			Other native species	N/A
			Salmonids	N/A
		Talbingo Reservoir, Yarrangobilly River Catchment and Upper Tumut River Catchment (below T2 Dam)	Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
		Upper Tantangara Creek	Threatened species - stocky galaxias	Mod
			Other native aquatic species	N/A
			Salmonids	N/A
		Mid Murrumbidgee River Catchment	Threatened aquatic species - Macquarie perch	Mod
			Threatened aquatic species - Murray cod and Murray cray	Mod
			Threatened aquatic species - Southern pygmy perch	Mod
			Native aquatic species - Mountain galaxias	Mod
			Other native aquatic species	Mod
			Salmonids	N/A
		Snowy River Catchment	Threatened Population - River blackfish	Mod
			Salmonids	N/A
			Other native species	Mod
			Snowy River EEC	Mod
		Geehi Reservoir / M2 Reservoir Catchment	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
		Swampy Plain River Catchment	Threatened aquatic species - Murray crayfish	Mod
			Native aquatic species	Mod
			Salmonids	N/A
		Talbingo Reservoir	Threatened aquatic species - Trout cod	Mod

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Threatened aquatic species - Murray crayfish	Mod
			Native aquatic Species	Mod
			Salmonids	N/A
			Phytoplankton Assemblages	Mod
		Tantangara Reservoir	Threatened aquatic Species	N/A
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Mod
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Low
	Indirect - plant and phytoplankton transfer leading to HABs	Upper Murrumbidgee River	Threatened aquatic species - Macquarie perch (low)	N/A
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Low
		Mid Murrumbidgee River	Threatened aquatic species - Macquarie perch	Low
			Threatened aquatic species - Murray Cod	Low
			Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Southern pygmy perch	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Low
		Lake Eucumbene	Threatened aquatic Species	N/A
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Low
	Indirect - proliferatoin of non-native aquatic plants	Talbingo Reservoir	Threatened aquatic species - Trout cod	N/A
			Threatened aquatic species - Murray crayfish	N/A
			Native aquatic Species	N/A
			Salmonids	N/A
			Phytoplankton Assemblages	N/A
		Tantangara Reservoir	Threatened aquatic Species	N/A
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Low
		Upper Murrumbidgee River	Threatened aquatic Species	N/A
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton Assemblages	Low
		Mid Murrumbidgee River	Threatened aquatic species - Macquarie perch	Low
			Threatened aquatic species - Murray Cod	Low
			Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Southern pygmy perch	Low

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton assemblages	Low
		Lake Eucumbene	Threatened aquatic Species	N/A
			Native aquatic Species	Low
			Salmonids	N/A
			Phytoplankton assemblages	Low
	Indirect - fish disease transfer leading to mortality	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic Species	Low
			Salmonids	N/A
		Tantangara Reservoir	Threatened aquatic Species	N/A
			Native aquatic Species	Mod
			Salmonids	N/A
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic Species	Low
			Salmonids	N/A
		Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Mod
			Native aquatic Species	Low
			Salmonids	N/A
		Upper Murrumbidgee River	Threatened aquatic species	N/A
			Native aquatic Species	Mod
			Salmonids	N/A
		Mid Murrumbidgee River	Threatened aquatic species - Macquarie perch	Low
			Threatened aquatic species - Murray Cod	Low
			Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Southern pygmy perch	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic Species	Mod
			Salmonids	N/A
		Lake Eucumbene	Threatened aquatic Species	N/A
			Native aquatic Species	Low
			Salmonids	N/A
Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Murrumbidgee River	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
	Indirect - changes to water quality due to tunnel dewatering (Point source)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
	Indirect - changes to water quality from diffuse surface run-off (Diffuse)	Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Upper Murrumbidgee River	Threatened aquatic species - Macquarie perch (low)	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	Low
		Talbingo Reservoir	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low

Activity	Potential Impact	Catchment	Receptor	Residual Risk
			Native aquatic species	Low
			Salmonids	N/A
			Planktonic assemblages	N/A
		Tantangara Reservoir	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
		Yarrangobilly River	Threatened aquatic species - Trout cod	Low
			Threatened aquatic species - Murray crayfish	Low
			Native aquatic species	Low
			Salmonids	N/A
	Indirect – spread of aquatic weeds and pest fish		Planktonic assemblages	N/A
		Upper Murrumbidgee River	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
		Lake Eucumbene	Threatened aquatic species	N/A
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A
		Upper Tantangara Creek	Threatened aquatic species - Stocky galaxias	Mod
			Native aquatic species	Mod
			Salmonids	N/A
			Planktonic assemblages	N/A

9.3 Threatened Species and Communities

The EPBC Act and FM Act provides formal protection to species that are scarce or their numbers have been substantially reduced over recent decades. The following species and endangered ecological community listed under the EBPC Act, FM Act or both are likely to occur within the study area (although not necessarily the area expected to be directly affected by project activities):

> Macquarie perch (Endangered (EPBC Act and FM Act));
> Trout cod (Endangered (EPBC Act and FM Act));
> Murray cod (Vulnerable (EPBC Act));
> River blackfish – Snowy River Catchment (Endangered (FM Act));
> Southern pygmy perch (Endangered (FM Act));
> Silver perch (Vulnerable (FM Act));
> Stocky galaxias (Critically endangered (FM Act));
> Eel-tailed catfish – Murray Darling Basin population (Endangered (FM Act));
> Murray crayfish (Vulnerable (FM Act));
> Alpine redspot dragonfly (Vulnerable (FM Act)); and
> Snowy River Endangered Ecological Community (Endangered ecological community (FM Act)).

Assessments of significance (AoS) were completed for each of these species and endangered ecological communities (**Annexure C**). In summary, based on the implementation of identified mitigation measures, the project is not anticipated to have a significant impact on these species or endangered ecological communities.

10 Conclusions

The Snowy Hydro Scheme is situated within a large geographical region comprising lakes and watercourses interconnected by natural and artificial water bodies. Many of the waterbodies in the project study contain important aquatic habitat and are of significant conservation value.

Construction and operational activities associated with Snowy 2.0 Main Works have potential to impact on aquatic ecology in some waterbodies in the project area, in particular the existing Talbingo and Tantangara reservoirs. The main potential for impact would be from construction activities within the reservoir and from the proposed connection between Talbingo Reservoir and Tantangara Reservoir, which would establish a new two-way hydrologic pathway between these reservoirs.

The management of risks to Aquatic Ecology would occur via the mitigation measures listed in **Section 9.1** above and through the development of a range of management plans. These would contain measures to construct the proposed development in a way that seeks to minimise negative impacts on the aquatic environment and enable appropriate responses to impacts that are identified. Identified moderate residual risks include potential impacts to biota due to elevated suspended fine material associated with placement of excavated rock within Talbingo Reservoir during construction and potential impacts associated with the transfer of pest species (fish and/or fish disease) between Talbingo and Tantangara reservoirs and into associated catchments during operation in the unlikely event of failure of all controls.

Mitigation of elevated TSS within Talbingo Reservoir would be primarily managed by deploying a silt curtain to minimise the spread of turbid water/suspended solids beyond the excavated material footprint and with strict adherence to the Dredging and Excavated Materials Management Plan and the Aquatic Habitat Management Plan.

In response to the risks of fish and/or fish disease transfer, Snowy Hydro has incorporated additional secondary controls at outflows of Tantangara Reservoir and above the waterfall on Tantangara Creek. These measures would limit the potential range expansion of any fish that may be transferred to Tantangara Reservoir as a result of the project and would prevent these fish from entering the known habitats of any threatened species including the Murrumbidgee River below Tantangara Reservoir and Lake Eucumbene. These controls are a result of considerable volumes of research and design development initiated by Snowy Hydro aimed at eliminating the potential risk to pre-existing fish populations and other components of aquatic ecology at risk from fish transfer.

Given these findings, consideration of the proposed safeguards and the potential option for offsets in the event inadvertent, irreparable damage to aquatic habitats or populations of biota occur, the project has acceptable outcomes to aquatic ecology values in the project study area.

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ANNEXURE

A

PMST RESULTS

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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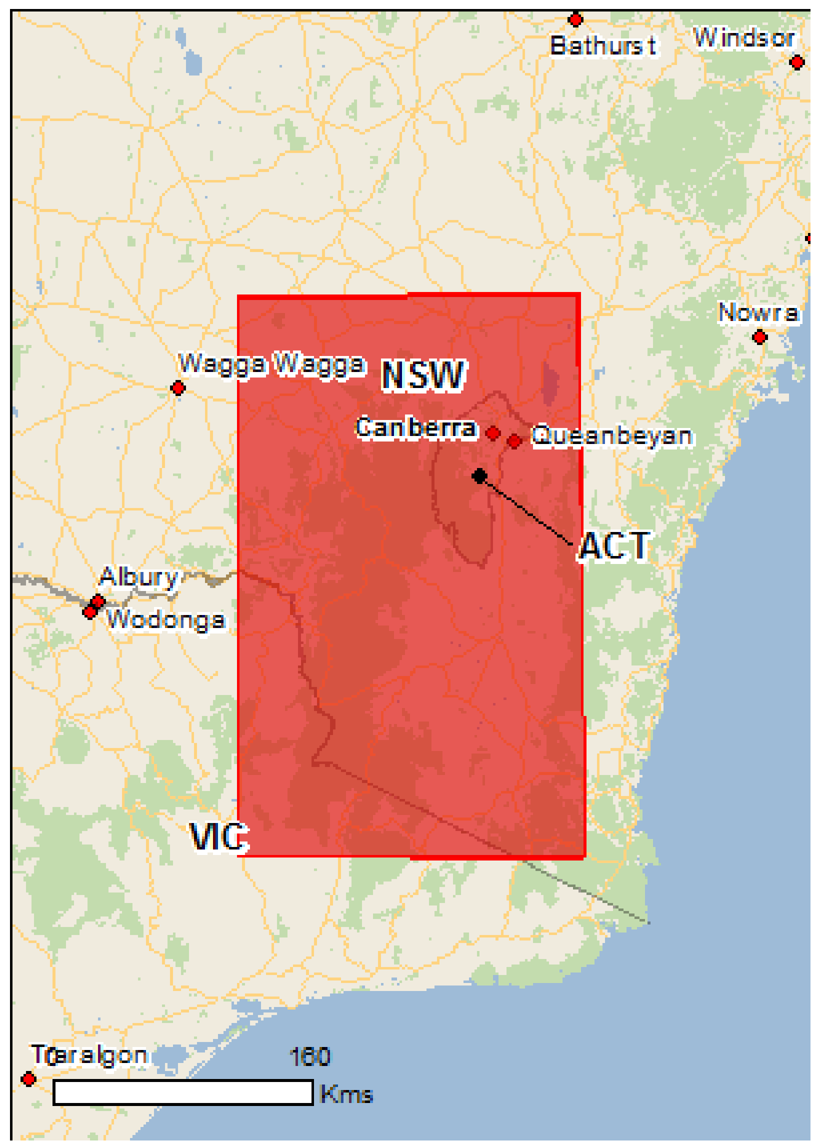

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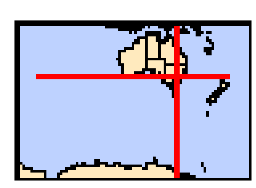

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	6
Wetlands of International Importance:	10
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	10
Listed Threatened Species:	121
Listed Migratory Species:	14

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	43
Commonwealth Heritage Places:	82
Listed Marine Species:	21
Whales and Other Cetaceans:	None
Critical Habitats:	1
Commonwealth Reserves Terrestrial:	1
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	207
Regional Forest Agreements:	5
Invasive Species:	50
Nationally Important Wetlands:	38
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

National Heritage Properties

[Resource Information]

Name	State	Status
Natural		
Australian Alps National Parks and Reserves	NSW	Listed place
Historic		
Australian Academy of Science Building	ACT	Listed place
Australian War Memorial and the Memorial Parade	ACT	Listed place
High Court - National Gallery Precinct	ACT	Listed place
Old Parliament House and Curtilage	ACT	Listed place
Snowy Mountains Scheme	NSW	Listed place

Wetlands of International Importance (Ramsar)

[Resource Information]

Name	Proximity
Banrock station wetland complex	600 - 700km upstream
Barmah forest	200 - 300km upstream
Blue lake	Within Ramsar site
Ginini flats wetland complex	Within Ramsar site
Gippsland lakes	50 - 100km upstream
Gunbower forest	200 - 300km upstream
Hattah-kulkyne lakes	400 - 500km upstream
Nsw central murray state forests	200 - 300km upstream
Riverland	600 - 700km upstream
The coorong, and lakes alexandrina and albert wetland	700 - 800km upstream

Listed Threatened Ecological Communities

[Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
	Endangered	Community may occur within area
	Endangered	Community likely to occur within area
	Endangered	Community likely to occur within area
Alpine Sphagnum Bogs and Associated Fens	Endangered	Community known to occur within area
Lowland Grassy Woodland in the South East Corner Bioregion	Critically Endangered	Community likely to occur within area
Natural Temperate Grassland of the South Eastern Highlands	Critically Endangered	Community likely to occur within area
Silurian Limestone Pomaderris Shrubland of the South East Corner and Australian Alps Bioregions	Endangered	Community known to occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Weeping Myall Woodlands	Endangered	Community may occur within area
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	Community likely to occur within area

Listed Threatened Species

[Resource Information]

Name	Status	Type of Presence
Birds		
Anthochaera phrygia Regent Honeyeater [82338]	Critically Endangered	Species or species habitat known to occur within area
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Dasyornis brachypterus Eastern Bristlebird [533]	Endangered	Species or species habitat may occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat known to occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat known to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Polytelis swainsonii Superb Parrot [738]	Vulnerable	Breeding known to occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Fish		
Bidyanus bidyanus Silver Perch, Bidyan [76155]	Critically Endangered	Species or species habitat known to occur within area
Galaxias rostratus Flathead Galaxias, Beaked Minnow, Flat-headed Galaxias, Flat-headed Jollytail, Flat-headed Minnow [84745]	Critically Endangered	Species or species habitat known to occur within area
Maccullochella macquariensis Trout Cod [26171]	Endangered	Species or species habitat likely to occur within area
Maccullochella peelii Murray Cod [66633]	Vulnerable	Species or species habitat known to occur within area
Macquaria australasica Macquarie Perch [66632]	Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Prototroctes maraena		
Australian Grayling [26179]	Vulnerable	Species or species habitat known to occur within area
Frogs		
Crinia sloanei		
Sloane's Froglet [59151]	Endangered	Species or species habitat may occur within area
Heleioporus australiacus		
Giant Burrowing Frog [1973]	Vulnerable	Species or species habitat known to occur within area
Litoria aurea		
Green and Golden Bell Frog [1870]	Vulnerable	Species or species habitat known to occur within area
Litoria booroolongensis		
Booroolong Frog [1844]	Endangered	Species or species habitat known to occur within area
Litoria castanea		
Yellow-spotted Tree Frog, Yellow-spotted Bell Frog [1848]	Critically Endangered	Species or species habitat likely to occur within area
Litoria littlejohni		
Littlejohn's Tree Frog, Heath Frog [64733]	Vulnerable	Species or species habitat likely to occur within area
Litoria raniformis		
Growling Grass Frog, Southern Bell Frog, Green and Golden Frog, Warty Swamp Frog [1828]	Vulnerable	Species or species habitat likely to occur within area
Litoria spenceri		
Spotted Tree Frog [25959]	Endangered	Species or species habitat known to occur within area
Litoria verreauxii alpina		
Alpine Tree Frog, Verreaux's Alpine Tree Frog [66669]	Vulnerable	Species or species habitat known to occur within area
Mixophyes balbus		
Stuttering Frog, Southern Barred Frog (in Victoria) [1942]	Vulnerable	Species or species habitat likely to occur within area
Pseudophryne corroboree		
Southern Corroboree Frog [1915]	Critically Endangered	Species or species habitat known to occur within area
Pseudophryne pengilleyi		
Northern Corroboree Frog [66670]	Critically Endangered	Species or species habitat known to occur within area
Insects		
Synemon plana		
Golden Sun Moth [25234]	Critically Endangered	Species or species habitat known to occur within area
Mammals		
Burramys parvus		
Mountain Pygmy-possum [267]	Endangered	Species or species habitat known to occur within area
Chalinolobus dwyeri		
Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus maculatus maculatus (SE mainland population)		
Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat known to occur within area
Isoodon obesulus obesulus		
Southern Brown Bandicoot (eastern), Southern	Endangered	Species or species

Name	Status	Type of Presence
Brown Bandicoot (south-eastern) [68050]		habitat known to occur within area
Mastacomys fuscus mordicus Broad-toothed Rat (mainland), Tooarrana [87617]	Vulnerable	Species or species habitat known to occur within area
Nyctophilus corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat likely to occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat known to occur within area
Petrogale penicillata Brush-tailed Rock-wallaby [225]	Vulnerable	Species or species habitat known to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Potorous longipes Long-footed Potoroo [217]	Endangered	Species or species habitat known to occur within area
Potorous tridactylus tridactylus Long-nosed Potoroo (SE Mainland) [66645]	Vulnerable	Species or species habitat known to occur within area
Pseudomys fumeus Smoky Mouse, Konoom [88]	Endangered	Species or species habitat known to occur within area
Pseudomys novaehollandiae New Holland Mouse, Pookila [96]	Vulnerable	Species or species habitat may occur within area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Roosting known to occur within area
Plants		
Acacia georgensis Bega Wattle [9848]	Vulnerable	Species or species habitat known to occur within area
Acacia phasmoides Phantom Wattle [2784]	Vulnerable	Species or species habitat known to occur within area
Ammobium craspedioides Yass Daisy [20758]	Vulnerable	Species or species habitat known to occur within area
Amphibromus fluitans River Swamp Wallaby-grass, Floating Swamp Wallaby-grass [19215]	Vulnerable	Species or species habitat known to occur within area
Argyrotegium nitidulum Shining Cudweed [82043]	Vulnerable	Species or species habitat known to occur within area
Austrostipa wakoolica [66623]	Endangered	Species or species habitat may occur within area
Baloskion longipes Dense Cord-rush [68511]	Vulnerable	Species or species habitat likely to occur within area
Boronia deanei Deane's Boronia [8397]	Vulnerable	Species or species habitat known to occur

Name	Status	Type of Presence
		within area
Caladenia actensis Canberra Spider Orchid [76138]	Critically Endangered	Species or species habitat known to occur within area
Caladenia arenaria Sand-hill Spider-orchid [9275]	Endangered	Species or species habitat may occur within area
Caladenia concolor Crimson Spider-orchid, Maroon Spider-orchid [5505]	Vulnerable	Species or species habitat likely to occur within area
Caladenia tensa Greencomb Spider-orchid, Rigid Spider-orchid [24390]	Endangered	Species or species habitat likely to occur within area
Caladenia tessellata Thick-lipped Spider-orchid, Daddy Long-legs [2119]	Vulnerable	Species or species habitat likely to occur within area
Calotis glandulosa Mauve Burr-daisy [7842]	Vulnerable	Species or species habitat known to occur within area
Colobanthus curtisiae Curtis' Colobanth [23961]	Vulnerable	Species or species habitat likely to occur within area
Commersonia prostrata Dwarf Kerrawang [87152]	Endangered	Species or species habitat known to occur within area
Corunastylis ectopa Brindabella Midge-orchid, Ectopic Midge-orchid [78973]	Critically Endangered	Species or species habitat known to occur within area
Cryptostylis hunteriana Leafless Tongue-orchid [19533]	Vulnerable	Species or species habitat likely to occur within area
Deyeuxia pungens Narrow-leaf Bent-grass [24421]	Vulnerable	Species or species habitat known to occur within area
Dianella amoena Matted Flax-lily [64886]	Endangered	Species or species habitat known to occur within area
Diuris aequalis Buttercup Doubletail [21588]	Vulnerable	Species or species habitat known to occur within area
Diuris ochroma Pale Golden Moths [64565]	Vulnerable	Species or species habitat likely to occur within area
Dodonaea procumbens Trailing Hop-bush [12149]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus aggregata Black Gum [20890]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus parvula Small-leaved Gum [56153]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus pulverulenta Silver-leaved Mountain Gum, Silver-leaved Gum [21537]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Euphrasia collina subsp. muelleri Purple Eyebright, Mueller's Eyebright [16151]	Endangered	Species or species habitat known to occur within area
Genoplesium vernale East Lynne Midge-orchid [68379]	Vulnerable	Species or species habitat likely to occur within area
Gentiana baeuerlenii Baeuerlen's Gentian [12001]	Endangered	Species or species habitat likely to occur within area
Gentiana bredboensis Bredbo Gentian [15882]	Critically Endangered	Species or species habitat known to occur within area
Glycine latrobeana Clover Glycine, Purple Clover [13910]	Vulnerable	Species or species habitat known to occur within area
Grevillea acanthifolia subsp. paludosa Bog Grevillea [21872]	Endangered	Species or species habitat known to occur within area
Grevillea iaspicula Wee Jasper Grevillea [22024]	Endangered	Species or species habitat known to occur within area
Grevillea wilkinsonii Tumut Grevillea [56396]	Endangered	Species or species habitat known to occur within area
Haloragis exalata subsp. exalata Wingless Raspwort, Square Raspwort [24636]	Vulnerable	Species or species habitat known to occur within area
Lepidium aschersonii Spiny Pepper-cress [10976]	Vulnerable	Species or species habitat likely to occur within area
Lepidium ginninderrense Ginninderra Peppercress [78474]	Vulnerable	Species or species habitat known to occur within area
Lepidium hyssopifolium Basalt Pepper-cress, Peppercress, Rubble Pepper-cress, Pepperweed [16542]	Endangered	Species or species habitat known to occur within area
Leucochrysum albicans var. tricolor Hoary Sunray, Grassland Paper-daisy [56204]	Endangered	Species or species habitat known to occur within area
Muehlenbeckia tuggeranong Tuggeranong Lignum [64934]	Endangered	Species or species habitat likely to occur within area
Nematolepis rhytidophylla [64936]	Vulnerable	Species or species habitat likely to occur within area
Nematolepis squamea subsp. coriacea Harsh Nematolepis [64937]	Vulnerable	Species or species habitat known to occur within area
Olearia astroloba Marble Daisy-bush [21881]	Vulnerable	Species or species habitat likely to occur within area
Pelargonium sp. Striatellum (G.W.Carr 10345) Omeo Stork's-bill [84065]	Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Persicaria elatior Knotweed, Tall Knotweed [5831]	Vulnerable	Species or species habitat may occur within area
Pomaderris cotoneaster Cotoneaster Pomaderris [2043]	Endangered	Species or species habitat known to occur within area
Pomaderris pallida Pale Pomaderris [13684]	Vulnerable	Species or species habitat known to occur within area
Pomaderris parrisiae Parris' Pomaderris [22119]	Vulnerable	Species or species habitat likely to occur within area
Prasophyllum bagoense Bago Leek-orchid [84276]	Critically Endangered	Species or species habitat known to occur within area
Prasophyllum frenchii Maroon Leek-orchid, Slaty Leek-orchid, Stout Leek-orchid, French's Leek-orchid, Swamp Leek-orchid [9704]	Endangered	Species or species habitat likely to occur within area
Prasophyllum innubum Brandy Marys Leek-orchid [83603]	Critically Endangered	Species or species habitat known to occur within area
Prasophyllum keltonii Kelton's Leek-orchid [83604]	Critically Endangered	Species or species habitat known to occur within area
Prasophyllum morganii Mignonette Leek-orchid, Cobungra Leek-orchid, Dense Leek-orchid [13804]	Vulnerable	Species or species habitat may occur within area
Prasophyllum petilum Tarengo Leek Orchid [55144]	Endangered	Species or species habitat known to occur within area
Pterostylis chlorogramma Green-striped Greenhood [56510]	Vulnerable	Species or species habitat may occur within area
Pterostylis oreophila Blue-tongued Orchid, Kiandra Greenhood [22903]	Critically Endangered	Species or species habitat known to occur within area
Pultenaea parrisiae [56699]	Vulnerable	Species or species habitat likely to occur within area
Ranunculus anemoneus Anemone Buttercup [14889]	Vulnerable	Species or species habitat likely to occur within area
Rutidosis leiolepis Monaro Golden Daisy [21490]	Vulnerable	Species or species habitat known to occur within area
Rutidosis leptorrhynchoides Button Wrinklewort [7384]	Endangered	Species or species habitat known to occur within area
Rytidosperma pumilum Feldmark Grass [66716]	Vulnerable	Species or species habitat likely to occur within area
Senecio macrocarpus Large-fruit Fireweed, Large-fruit Groundsel [16333]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Senecio psilocarpus Swamp Fireweed, Smooth-fruited Groundsel [64976]	Vulnerable	Species or species habitat likely to occur within area
Swainsona recta Small Purple-pea, Mountain Swainson-pea, Small Purple Pea [7580]	Endangered	Species or species habitat known to occur within area
Thesium australe Austral Toadflax, Toadflax [15202]	Vulnerable	Species or species habitat known to occur within area
Tylophora linearis [55231]	Endangered	Species or species habitat may occur within area
Westringia kydrensis [56456]	Endangered	Species or species habitat known to occur within area
Xerochrysum palustre Swamp Everlasting, Swamp Paper Daisy [76215]	Vulnerable	Species or species habitat known to occur within area
Zieria citriodora Lemon-scented Zieria [56731]	Vulnerable	Species or species habitat known to occur within area
Zieria tuberculata Warty Zieria [56736]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Aprasia parapulchella Pink-tailed Worm-lizard, Pink-tailed Legless Lizard [1665]	Vulnerable	Species or species habitat known to occur within area
Cyclodomorphus praealtus Alpine She-oak Skink [64721]	Endangered	Species or species habitat known to occur within area
Delma impar Striped Legless Lizard [1649]	Vulnerable	Species or species habitat known to occur within area
Liopholis guthega Guthega Skink [83079]	Endangered	Species or species habitat known to occur within area
Tympanocryptis pinguicolla Grassland Earless Dragon [66727]	Endangered	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Breeding known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Commonwealth Land - Airservices Australia
Commonwealth Land - Australian & Overseas Telecommunications Corporation
Commonwealth Land - Australian Postal Commission
Commonwealth Land - Australian Postal Corporation
Commonwealth Land - Australian Telecommunications Commission
Commonwealth Land - Australian Telecommunications Corporation
Commonwealth Land - Commonwealth Bank of Australia
Commonwealth Land - Commonwealth Scientific & Industrial Research Organisation
Commonwealth Land - Commonwealth Trading Bank of Australia
Commonwealth Land - Defence Housing Authority
Commonwealth Land - Defence Service Homes Corporation
Commonwealth Land - Telstra Corporation Limited
Defence - 10 WHYALLA ST - FYSHWICK
Defence - 139 CANBERRA AVE - FYSHWICK
Defence - 169 GLADSTONE ST - FYSHWICK
Defence - ADC / JSSC - WESTON

Name
Defence - ADFA MARINE FACILITY - YARRALUMLA
Defence - AIDAB Building
Defence - AUSTRALIAN DEFENCE FORCE ACADEMY
Defence - BELCONNEN RADIO STATION ; BELCONNEN COMMUNICATIONS STATION
Defence - CAMPBELL PARK
Defence - CHURCHES CENTRE - TUGGERANONG
Defence - COOMA ARMY TRAINING DEPOT (COOMA RESERVE DEPOT)
Defence - DEAKIN OFFICES
Defence - DEFENCE ARCHIVES - QUEANBEYAN
Defence - DEFENCE RECRUITING UNIT - GIO BUILDING
Defence - HEWLETT PACKARD BUILDING - FERNHILL PARK
Defence - HMAS HARMAN - SYMONSTOWN
Defence - MAJURA FIELD FIRING RANGE
Defence - MAJURA NAVIGATION BEACON
Defence - MAJURA NAVIGATIONAL AID SITE
Defence - MAWSON OFFICE ACCOMM
Defence - MT JERRABOMBERRA OBSTRUCTION WARNING
Defence - NAVAL COMBAT DATA SYSTEM CENTRE - FYSHWICK
Defence - NCC BUILDING - CANBERRA CITY
Defence - NORTHBOURNE HOUSE
Defence - NORTHCOTT DRIVE PLAYING FIELDS (Addison Rd)
Defence - PHYSICS FIELD TESTING STATION - CANBERRA
Defence - RAAF BASE FAIRBAIRN
Defence - ROYAL MILITARY COLLEGE - DUNTROON
Defence - RUSSELL HILL COMPLEX
Defence - WERRIWA DEPOT

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Majura Valley Natural Temperate Grassland	ACT	Listed place
State Circle Cutting	ACT	Listed place
Synemon Plana Moth Habitat	ACT	Listed place
Indigenous		
Aboriginal Embassy Site	ACT	Within listed place
Historic		
Acton Conservation Area	ACT	Listed place
Acton Peninsula Building 1	ACT	Listed place
Acton Peninsula Building 15	ACT	Listed place
Acton Peninsula Building 2	ACT	Listed place
Acton Peninsula Limestone Outcrops	ACT	Listed place
Anzac Memorial Chapel of St Paul	ACT	Listed place
Apostolic Nunciature	ACT	Listed place
Apple Shed Asset C58	ACT	Listed place
Australian American Memorial and Sir Thomas Blamey Square	ACT	Listed place
Australian Forestry School (former)	ACT	Listed place
Australian National Botanic Gardens (part)	ACT	Listed place
Australian War Memorial	ACT	Listed place
Blundells Farmhouse, Slab Outbuilding and Surrounds	ACT	Listed place
CSIRO Main Entomology Building	ACT	Listed place
Cameron Offices (Wings 3, 4 and 5, and Bridge)	ACT	Listed place
Canberra School of Art	ACT	Listed place
Canberra School of Music	ACT	Listed place
Captains Quarters Assets B1 to B4	ACT	Listed place
Carillon	ACT	Listed place
Casey House and Garden	ACT	Listed place
Changi Chapel	ACT	Listed place
Commandants House Asset B9	ACT	Listed place
Commencement Column Monument	ACT	Listed place
Communications Centre	ACT	Listed place
Drill Hall Gallery	ACT	Listed place
Duntroon House and Garden	ACT	Listed place
East Block Government Offices	ACT	Listed place
Edmund Barton Offices	ACT	Listed place
General Bridges Grave	ACT	Listed place
Googong Foreshores Cultural and Geodiversity Heritage	NSW	Listed place

Name	State	Status
Areas		
Gungahlin Complex	ACT	Listed place
Gungahlin Homestead and Landscape	ACT	Listed place
High Court - National Gallery Precinct	ACT	Listed place
High Court of Australia	ACT	Listed place
Institute of Anatomy (former)	ACT	Listed place
John Gorton Building	ACT	Listed place
King George V Memorial	ACT	Listed place
Lennox House Complex	ACT	Listed place
Mount Stromlo Observatory Precinct	ACT	Listed place
National Gallery of Australia	ACT	Listed place
National Library of Australia and Surrounds	ACT	Listed place
National Rose Gardens	ACT	Listed place
Old Parliament House Gardens	ACT	Listed place
Old Parliament House and Curtilage	ACT	Listed place
Parade Ground and Associated Buildings Group	ACT	Listed place
Parliament House Vista	ACT	Listed place
Parliament House Vista Extension - Portal Buildings	ACT	Listed place
Patent Office (former)	ACT	Listed place
Phytotron	ACT	Listed place
R G Menzies Building ANU	ACT	Listed place
RMC Duntroon Conservation Area	ACT	Listed place
Redwood Plantation	ACT	Listed place
Reserve Bank of Australia	ACT	Listed place
Residence Asset B5	ACT	Listed place
Residence Asset B7	ACT	Listed place
Residence Asset C12	ACT	Listed place
Residence Asset C13	ACT	Listed place
Residence Asset C14	ACT	Listed place
Residence Asset C15	ACT	Listed place
Residence Asset C7	ACT	Listed place
Residence Asset C8	ACT	Listed place
Royal Australian Naval Transmitting Station	ACT	Listed place
Russell Precinct Heritage Area	ACT	Listed place
Sculpture Garden National Gallery of Australia	ACT	Listed place
The CSIRO Forestry Precinct	ACT	Listed place
The Lodge	ACT	Listed place
The Royal Australian Mint	ACT	Listed place
The Surveyors Hut	ACT	Listed place
Three Wartime Bomb Dump Buildings	ACT	Listed place
Toad Hall ANU	ACT	Listed place
Tumut Post Office	NSW	Listed place
University House and Garden	ACT	Listed place
West Block and the Dugout	ACT	Listed place
Westridge House & Grounds	ACT	Listed place
Yarralumla and Surrounds	ACT	Listed place
Yass Post Office	NSW	Listed place
York Park North Tree Plantation	ACT	Listed place
Russell Cafeteria	ACT	Within listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Breeding known to occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Breeding known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat known to occur within area

Critical Habitats	[Resource Information]
Name	Type of Presence
Lepidium ginninderrense (Ginninderra Peppercress) - Northwest corner Belconnen Naval Transmission Station, ACT	Listed Critical Habitat

Commonwealth ReservesTerrestrial		[Resource Information]
Name	State	Type
Australian National	ACT	Botanic Gardens

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Alpine National Park	VIC
Aranda Bushland	ACT
Badja Swamps	NSW
Bago	NSW
Bald Hills Road B.R.	VIC
Bango	NSW
Beehive Creek	VIC
Belmount	NSW
Bendoc N.C.R.	VIC
Bimberi	NSW
Bimberi Wilderness	ACT
Binjura	NSW
Black Andrew	NSW
Black Mountain	ACT
Bobundara	NSW
Bogandyera	NSW
Bondi Gulf	NSW
Bowen	VIC
Brindabella	NSW
Bruce Ridge	ACT
Buchan Headwaters	VIC
Buenba	VIC
Bullen Range	ACT
Burbibyong Creek	VIC
Burnt School	NSW
Burra Creek	NSW
Burrinjuck	NSW
Burrowa - Pine Mountain National Park	VIC
Callum Brae	ACT
Carabost	NSW
Clarke Lagoon W.R	VIC
Clarkes Hill	NSW
Cobberas	VIC
Colac Colac B.R.	VIC
Concordia Gully	VIC
Cooleman Ridge	ACT
Coolumbooka	NSW
Coornartha	NSW
Corryong Creek K33 SS.R.	VIC
Corryong Creek K34 SS.R.	VIC
Corryong Creek K35 SS.R.	VIC
Courabyra	NSW
Crace	ACT
Cuumbeun	NSW
Dangelong	NSW
Davies Plain	VIC
Deddick River SS.R.	VIC

Name	State
Delegate River SS.R.	VIC
Deua	NSW
Downfall	NSW
Dunlop Grassland	ACT
Eden Region	NSW
Ellerslie	NSW
Errinundra National Park	VIC
Eurabbie	NSW
Farrer Ridge	ACT
Forest Hill	VIC
Forestry Management Areas in Badja	NSW
Forestry Management Areas in Bago-Maragle	NSW
Forestry Management Areas in Eden	NSW
Forestry Management Areas in Monaro South	NSW
Forestry Management Areas in Queanbeyan	NSW
Forestry Management Areas in Tumut	NSW
Gattamurh Creek	VIC
Gelantipy Plateau	VIC
Gigerline	ACT
Good Good	NSW
Goodwin Creek B.R.	VIC
Goorooyarroo	ACT
Goorooyarroo	NSW
Gossan Hill	ACT
Gourock	NSW
Gungaderra Grassland	ACT
Hattons Corner	NSW
Helms	NSW
Indi	VIC
Ironmungy	NSW
Isaacs Ridge	ACT
Jemba	VIC
Jeremal W.R	VIC
Jerrabattgulla	NSW
Jerrabomberra Wetlands	ACT
Jingellic	NSW
Kama	ACT
Kinleyside	ACT
Kosciuszko	NSW
Kuma	NSW
Kybeyan	NSW
Kybeyan	NSW
Laurel Hill	NSW
Letts Mountain	NSW
Little Bog Creek F.F.R.	VIC
Log Bridge Ck - East Branch	VIC
Lower Molonglo River Corridor	ACT
Macanally	NSW
Macfarlane Lookout N.F.S.R.	VIC
Marble Gully - Mount Tambo N.C.R.	VIC
McQuoids Hill	ACT
Mcleods Creek	NSW
Meringo	NSW
Merriangaah	NSW
Micalong Swamp	NSW
Minjary	NSW
Molonglo Gorge	ACT
Morass Creek F.F.R	VIC
Mount Bendock B.R	VIC
Mount Burrowa Area	VIC
Mount Clifford	NSW
Mount Delegate S.R	VIC
Mount Dowling	NSW
Mount Gelantipy Creek	VIC
Mount Gibbo N.F.S.R.	VIC
Mount Mitta Mitta F.R.	VIC

Name	State
Mount Poole	NSW
Mt Ainslie	ACT
Mt Majura	ACT
Mt Mugga Mugga	ACT
Mt Painter	ACT
Mt Pleasant	ACT
Mt Taylor	ACT
Mudjarn	NSW
Mulanggari Grassland	ACT
Mulligans Flat	ACT
Mundaroo	NSW
Mundoonen	NSW
Musket Creek	VIC
Myalla	NSW
Namadgi	ACT
Ngadang	NSW
Nimmo	NSW
Numeralla	NSW
Nunnett Plain N.F.S.R.	VIC
Nunniong Plain N.F.S.R.	VIC
O'Connor Ridge	ACT
Oak Creek	NSW
Oakdale	NSW
Oakey Hill	ACT
Old Jeremiah	NSW
Old Naas TSR	ACT
Paddys River	NSW
Paupong	NSW
Percival Hill	ACT
Pine Mountain	VIC
Queanbeyan	NSW
Quidong	NSW
Red Hill	ACT
River Murray Reserve	VIC
River Murray Reserve (non-PV)	VIC
Rob Roy	ACT
Rodger River and Mountain Creek	VIC
Scabby Range	NSW
Scottsdale	NSW
Snowy River	VIC
Snowy River	VIC
Snowy River National Park	VIC
South Coast Subregion of Southern Region	NSW
South East Forest	NSW
Stony Creek	ACT
Stony Creek	NSW
Stony Creek	VIC
Stony Creek SS.R	VIC
Strike-a-Light	NSW
Suggan Buggan	VIC
Suggan Buggan and Berrima Rivers	VIC
Swamp Creek	ACT
Tallaganda	NSW
Tallaganda	NSW
Tarcutta Hills	NSW
Tennyson Creek	NSW
Terlite-Munjie B.R.	VIC
The Pinnacle	ACT
Tidbinbilla	ACT
Tinderry	NSW
Tingaringy	VIC
Tintaldra W.R	VIC
Tom Groggin	VIC
Tongio B.R.	VIC
Towong B.R	VIC
Tuggeranong Hill	ACT

Name	State
Tumblong	NSW
Tumut Subregion of Southern Region	NSW
Turallo	NSW
Ulandra	NSW
Undoo	NSW
Unnamed	ACT
Upper Buchan River	VIC
Upper Snowy Area	VIC
Urambi Hills	ACT
Wabba	VIC
Wadbilliga	NSW
Wadjan	NSW
Wallaby Creek	VIC
Wallagaraugh	NSW
Wanna Wanna	NSW
Wanniassa Hills	ACT
Wee Jasper	NSW
Wereboldera	NSW
West Jerrabomberra	ACT
Wild Boar Range N.F.S.R.	VIC
Woodstock	ACT
Woomargama	NSW
Wulgulmerang Creek B.R.	VIC
Wullwye	NSW
Yanununbeyan	NSW
Yanununbeyan	NSW
Yanununbeyan	NSW
Yaouk	NSW

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included.

Name	State
East Gippsland RFA	Victoria
Eden RFA	New South Wales
Gippsland RFA	Victoria
North East Victoria RFA	Victoria
Southern RFA	New South Wales

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Alauda arvensis Skylark [656]		Species or species habitat likely to occur within area
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Carduelis chloris European Greenfinch [404]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Feral deer Feral deer species in Australia [85733]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus norvegicus Brown Rat, Norway Rat [83]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Plants		
Alternanthera philoxeroides Alligator Weed [11620]		Species or species habitat likely to occur within area
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Austrocylindropuntia spp. Prickly Pears [85132]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Chrysanthemoides monilifera subsp. monilifera Boneseed [16905]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera subsp. rotundata Bitou Bush [16332]		Species or species habitat likely to occur within area
Cylindropuntia spp. Prickly Pears [85131]		Species or species habitat likely to occur within area
Cytisus scoparius Broom, English Broom, Scotch Broom, Common Broom, Scottish Broom, Spanish Broom [5934]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Genista linifolia Flax-leaved Broom, Mediterranean Broom, Flax Broom [2800]		Species or species habitat likely to occur within area
Genista monspessulana Montpellier Broom, Cape Broom, Canary Broom, Common Broom, French Broom, Soft Broom [20126]		Species or species habitat likely to occur within area
Genista sp. X Genista monspessulana Broom [67538]		Species or species habitat may occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Nassella neesiana Chilean Needle grass [67699]		Species or species habitat likely to occur within area
Nassella trichotoma Serrated Tussock, Yass River Tussock, Yass Tussock, Nassella Tussock (NZ) [18884]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Pinus radiata Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Sagittaria platyphylla Delta Arrowhead, Arrowhead, Slender Arrowhead [68483]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Senecio madagascariensis Fireweed, Madagascar Ragwort, Madagascar Groundsel [2624]		Species or species habitat likely to occur within area
Solanum elaeagnifolium Silver Nightshade, Silver-leaved Nightshade, White Horse Nettle, Silver-leaf Nightshade, Tomato Weed, White Nightshade, Bull-nettle, Prairie-berry, Satansbos, Silver-leaf Bitter-apple, Silverleaf-nettle, Trompillo [12323]		Species or species habitat likely to occur within area
Ulex europaeus Gorse, Furze [7693]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Bega Swamp	NSW
Bendora Reservoir	ACT
Bethungra Dam Reserve	NSW
Big Badja Swamp	NSW
Blue Lake (Kosciuszko)	NSW
Coopers Swamp	NSW
Coree Flats	NSW
Cotter Flats	ACT
Cotter Source Bog	ACT
Davies Plain	VIC
Ginini and Cheyenne Flats	ACT
Horse Park Wetland	ACT
Jacksons Bog	NSW
Jerrabomberra Wetlands	ACT
Kosciusko Alpine Fens, Bogs and Lakes	NSW
Lake Dartmouth	VIC
Lake George	NSW
Micalong Swamp	NSW
Monaro Lakes	NSW
Nuniong Plateau Peatlands	VIC
Nunnock Swamp	NSW
Nursery Swamp	ACT
Packers Swamp	NSW
Rennex Gap	NSW
Rock Flats	ACT
Rotten Swamp	ACT
Scabby Range Lake	ACT
Snowgum Flat	NSW
Snowy Flats	ACT

Name	State
Snowy River	VIC
Suggan Buggan and Berrima Rivers	VIC
Tea Tree Swamp (Delegate River)	VIC
Tomneys Plain	NSW
Tomneys Plain	NSW
Upper Buchan River	VIC
Upper Cotter River	ACT
Upper Naas Creek	ACT
Yaouk Swamp	NSW

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-34.701295 147.692698,-34.684296 149.577455,-37.211195 149.612874,-37.204813 147.695256,-34.701295 147.692698

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Department of the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

ANNEXURE

B

BACKGROUND INFORMATION

Cardno®

Annexure B - Existing Aquatic Ecology

Snowy 2.0 Main Works

59918111

Prepared for
EMM Consulting Pty Ltd

13 September 2019

Rev0

Cardno

Table of Contents

Tables

Figures

Glossary and Abbreviations

BoM	Bureau of Meteorology
BC Act	NSW *Biodiversity Conservation Act 2016*
Cardno	Cardno NSW/ACT Pty Ltd
EMM	EMM Consulting
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
EHNV	Epizootic Haematopoietic Necrosis Virus
FL	Fork Length
FM Act	*NSW Fisheries Management Act 1994*
FSL	Full supply Level
KFH	Key fish Habitat
MOL	Minimum operating level
OCL	Occipital Carapace Length (mm)
OTU	Operational Taxonomic Unit
Project Area	The project area is the broader region within which Snowy 2.0 would be built and operated, and the extent within which direct impacts from the project are anticipated
qPCR	Quantitative Polymerase Chain Reaction. A widely used molecular biology technique to amplify and detect DNA and RNA sequences
RCE	Riparian, Channel and Environmental Inventory method (Chessman et al., 1997)
Snowy Hydro	Snowy Hydro Limited
Snowy Scheme	Snowy Mountains Hydro-Electric Scheme
Study area	Study area for the Aquatic Ecology Assessment
TN	Total Nitrogen
TP	Total Phosphorous

1 Introduction

1.1 Purpose

The purpose of this annexure is to provide detailed descriptions of the existing aquatic ecology within Talbingo Reservoir and Tantangara Reservoir and associated waterways within the study area.

The baseline ecological information compiled in this report establishes the ecological values of each of the catchments in the study area. The assessment of impacts, risk assessments and recommended mitigation measures are in the Aquatic Ecology Assessment (AEA) technical report.

Broadly, this annexure has been prepared with information compiled from a variety of sources including desktop reviews of publicly available databases, findings of previous studies, data from existing monitoring programs undertaken by Snowy Hydro Limited (Snowy Hydro) and fieldwork undertaken by Cardno and other organisations for the Snowy 2.0 Project.

1.2 Annexure Structure

This annexure comprises the following sections:

> Section 2 - The Study Area;
> Section 3 - Methodology;
> Section 4 - Synthesis of Literature, Databases and Monitoring Data;
> Section 5 - Field Survey Results;
> Section 6 - Likelihood of Occurrence; and
> Section 7 - References.

2 The Study Area

The study area encompasses the reservoirs and catchments that may be affected (both directly and indirectly) by Snowy 2.0 Main Works. The study area includes Talbingo Reservoir, Tantangara Reservoir and sub-catchments of the Tumut River, Murrumbidgee River, Murray River and Snowy River Catchments (e.g. the Eucumbene Sub-catchment in the Snowy River Catchment). These components were based on various ecological and physical criteria, primarily geographic context, hydrological connectivity (i.e. the presence of artificial and natural barriers to the movement of aquatic biota), broad aquatic habitat type (e.g. still ('lentic") versus flowing ("lotic") water) and the known distribution of key species, and a range of potential impacting processes. This approach helped conceptualise and discriminate the different ecological attributes that may be affected by the Snowy 2.0 Main Works, and thereby facilitated the impact assessment. It is important to note that the catchments described in this section do not represent a list of catchments that will be impacted by the project, but rather provide clear definition and description of catchments that can be subsequently referred to in the impact assessment.

Table 2-1, Figure 2-1 and **Figure 2-2** identify the components of the study area and provide an indication of the investigations undertaken to describe the aquatic ecology of the study area.

Table 2-1 Description of the study area, including Talbingo Reservoir, Tantangara Reservoir and the associated catchments and sub-catchments.

Component of study area	Primary Waterbodies
Tumut River Catchment	
Talbingo Reservoir	Talbingo Reservoir up to full supply level (FSL)
Yarrangobilly River Catchment	Yarrangobilly River including Wallace's Creek, Lick Hole Creek, Sheep Station Creek, Cave Gully upstream of Talbingo Reservoir FSL.
Upper Tumut River Catchment	Tumut River below Tumut 2 Reservoir dam wall and all other tributaries flowing into Talbingo Reservoir upstream of FSL (except Yarrangobilly River Catchment, see above).
T2 Reservoir Catchment	Tumut River upstream of Tumut 2 Reservoir, including Tumut Pond Reservoir, Tumut River and their tributaries upstream to Happy Jacks Pondage dam wall.
Blowering Reservoir Catchment	Blowering Reservoir catchment downstream of Talbingo Reservoir dam wall, including Blowering Reservoir, Jounama Pondage, and associated tributaries.
Lower Tumut Catchment	Catchment of the Tumut River from Blowering dam wall to the confluence with the Murrumbidgee River
Murrumbidgee River Catchment	
Tantangara Reservoir	Tantangara Reservoir up to FSL
Upper Murrumbidgee Catchment	Tributaries of Tantangara Reservoir, including the upper Murrumbidgee River, Tantangara Creek up to Tantangara Creek Waterfall just upstream of Alpine Creek Trail, Nungar Creek, Gooandra Creek, Kelly's Plain Creek, Mufflers Creek, Mosquito Creek and Goodradigbee River above the diversion weir.
Upper Tantangara Creek	Tantangara Creek upstream of Tantangara Creek Waterfall (just upstream of Alpine Creek Trail crossing).
Mid Murrumbidgee River Catchment	Murrumbidgee River Catchment between Tantangara Dam and ACT/NSW Border), including Murrumbidgee River, Numeralla River and other tributaries.
Lower Murrumbidgee River Catchment	Murrumbidgee River Catchment from the ACT/NSW border downstream to Lake Burrinjuck. Includes the Goodradigbee River below the diversion weir with its confluence at Lake Burrinjuck.
Lake Eucumbene and Snowy River Catchment	
Lake Eucumbene Catchment	Eucumbene Reservoir up to FSL and its tributaries, including the upper Eucumbene River, Gang Gang Creek and Three Mile Creek.
Lake Jindabyne Catchment	Lake Jindabyne up to FSL and its tributaries, including Snowy River Catchment upstream of Lake Jindabyne to Island Bend dam wall, Gungarlin River Catchment upstream to Burrungubugee and Gungarlin Weirs and Thredbo River.
Lower Snowy River Catchment	Snowy River and its tributaries downstream of Lake Jindabyne dam wall.
Murray River Catchment	

Component of study area	Primary Waterbodies
Murray River Catchment	Murray River Catchment from its headwaters downstream to Hume Reservoir including the Swampy Plains River catchment below Khancoban dam wall
Swampy Plain River Catchment	Swampy Plain River upstream of Khancoban dam wall, including Khancoban Reservoir and associated tributaries including Khancoban Back Creek to M2 Reservoir dam wall and Geehi River to Geehi Reservoir dam wall.
Geehi River and Murray 2 (M2) Reservoir Catchments	Geehi River catchment from Geehi Dam upstream (including Geehi Reservoir) and Khancoban Back Creek catchment from M2 dam wall (including M2 Reservoir) upstream.

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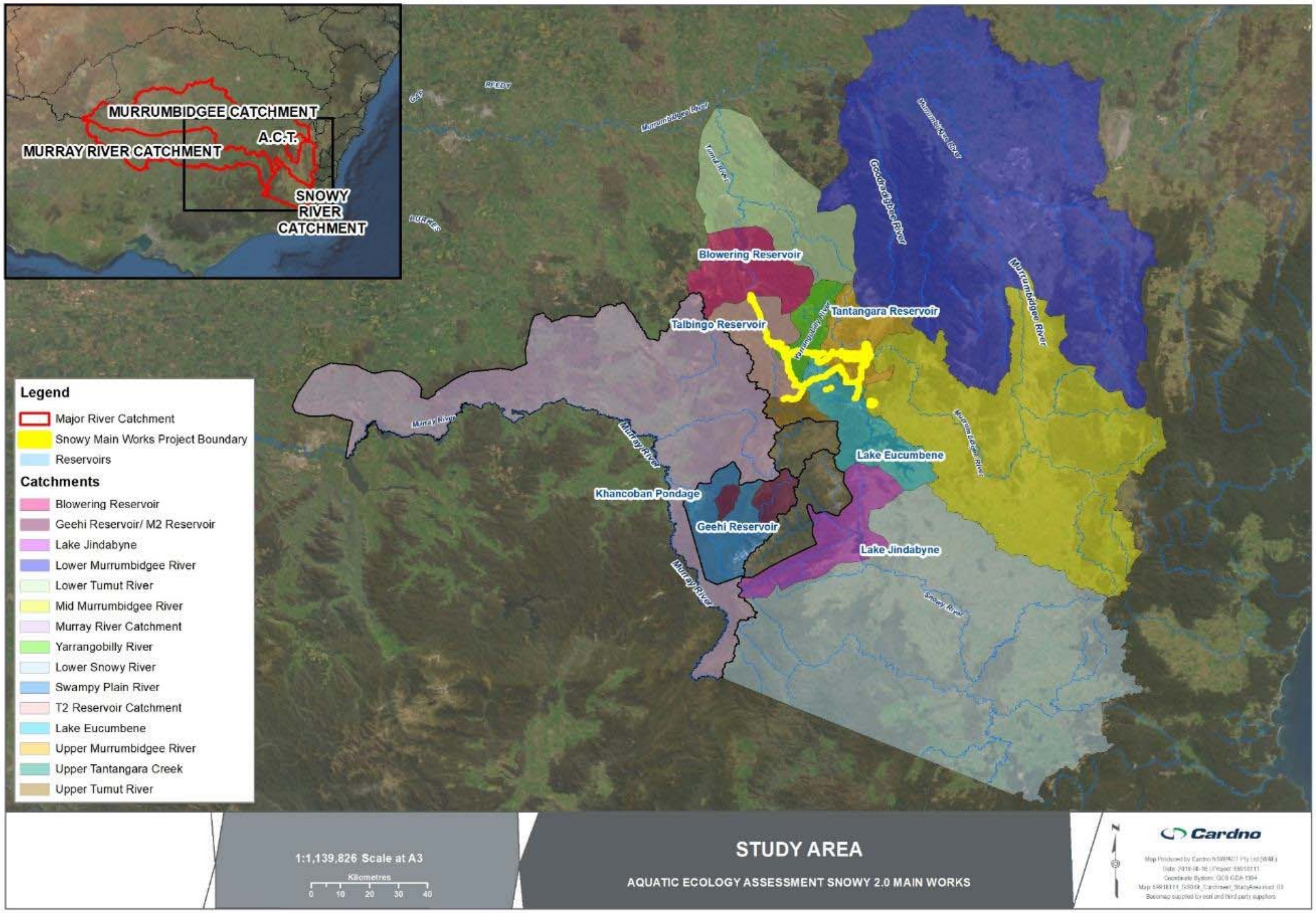


Figure 2-1 Study area overlain on the regional catchment boundaries.

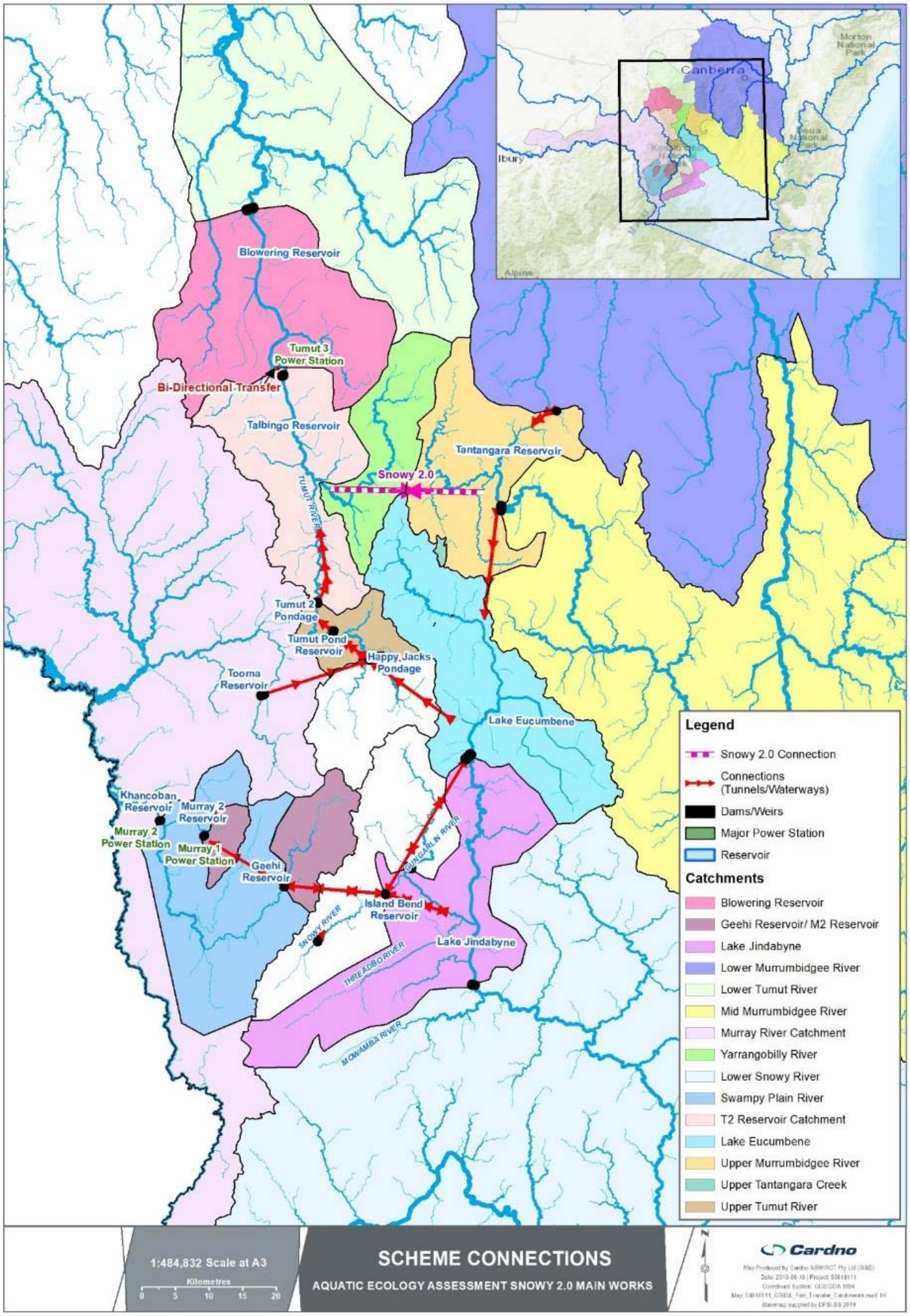


Figure 2-2 Current and proposed (Snowy 2.0) hydrological connections and major impoundments, barriers (dams and weirs) in the study area, overlaid with catchment boundaries

3 Methodology

The existing ecological values and the species present within the study area were described using information obtained from the following general sources:

> Databases searches;
> Desktop review of existing literature and existing monitoring programs; and
> Specific fieldwork undertaken for the project.

3.1 Databases Searches

Searches of the following databases and literature informed the understanding of listed threatened aquatic species, populations and communities throughout the study area:

> NSW Department of Primary Industries (DPI) Fish communities and threatened species distribution of NSW (NSW DPI, 2016a). The presence of suitable habitat in NSW DPI (2016a) is based on landscape and flow features and does not consider impacts such as (but not limited to) barriers to fish passage, thermal pollution and the presence of pest fish species;
> NSW DPI Listed threatened species, populations and ecological communities website: https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current;
> Department of the Environment and Energy (DoEE) (formerly Department of the Environment) Protected Matters Search Tool (PMST): http://www.environment.gov.au/epbc/protected-matters-search-tool;
> Atlas of Living Australia (ALA) (ALA, 2019);
> NSW Aquatic Pest and Disease Distribution: https://www.dpi.nsw.gov.au/fishing/pests-diseases/pest-disease-distribution;
> NSW WeedWise: http://weeds.dpi.nsw.gov.au/;
> Bureau of Meteorology (BoM) Groundwater Dependent Ecosystems Atlas: http://www.bom.gov.au/water/groundwater/gde/map.shtml;
> Fish communities of the Murrumbidgee catchment: Status and trends (Gilligan, 2005);
> Changes in fish assemblages after the first flow releases to the Snowy River downstream of Jindabyne Dam (Gilligan & Williams, 2008); and
> Fishes of the Murray-Darling Basin. An Introductory Guide (Lintermans, 2007).

Numerous other publications were reviewed to inform the assessment and are referenced where relevant.

Sensitive ecological sites (e.g. conservation areas, wetlands and other reserves) and areas protected by State and local environmental planning instruments due to their ecological significance were also identified using the:

> NSW DPI Critical habitat register: http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/what/register;
> NSW DPI Key Fish Habitat (KFH) maps: http://www.dpi.nsw.gov.au/fishing/habitat/publications/pubs/key-fish-habitat-maps; and
> NSW National Parks and Wildlife Service: http://www.nationalparks.nsw.gov.au/visit-a-park.

3.2 Review of Existing Literature and Monitoring Programs

Numerous publications and data from past or existing monitoring programs were reviewed to inform the understanding of listed threatened aquatic species, populations and communities throughout the study area.

3.2.1 Review of Fish Distributions

Lintermans (2019) reviewed information regarding known/likely fish distribution in those parts of the study area in the Upper Tumut Catchment (upstream of Talbingo Reservoir FSL to around Blowering Reservoir) and Upper Murrumbidgee River Catchment (from Cooma upstream to above Tantangara Reservoir) and identified the presence, or likely presence, of 18 fish species. This included 10 native fish species and eight non-native species (including one translocated native species). Six of the 10 native species are listed as threatened under the NSW *Fisheries Management Act 1994* (FM Act) or Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In addition, Lintermans (2019) recorded three invasive pest species of concern: redfin perch, climbing galaxias and eastern gambusia.

3.2.2 NSW DPI Catch Data

Data collected by NSW DPI (Fisheries) during various surveys (primarily backpack and boat-based electrofishing) undertaken over the period between April 1998 and February 2017 within the Snowy River catchment and immediately downstream of Talbingo and Tantangara dams were examined (NSW DPI, 2017b). These data have been included in the fish distribution descriptions in Section 5.7 and the fish record maps in Annexure B.

NSW DPI undertakes a program of fishing stocking in NSW waterways. Stocking includes native species (e.g. trout cod) and non-native species (e.g. rainbow trout). Stocking data are published online and were used to understand stocking activities that are undertaken throughout the study area. Recent data, not yet available online was also supplied directly by DPI (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. June 2019)

3.2.3 Phytoplankton Monitoring Data

Phytoplankton data have been collected within Talbingo and Tantangara Reservoirs by Snowy Hydro as part of an ongoing monitoring program since 1998 (multiple times per year). Data include details on total phytoplankton abundance (as cell counts) and on key phytoplankton taxa such as Cyanophyta (blue-green algae), Bacillariophyceae (diatoms), Chlorophyta (green algae), Chrysophyceae (golden algae), Cryptophyceae, Euglenophyta and Pyrrophyta.

3.3 Field Surveys

3.3.1 Overview

Targeted field surveys were undertaken for the AEA to characterise the aquatic flora and fauna in the project area and other selected locations. These were undertaken at Talbingo and Tantangara reservoirs, and in watercourses flowing into and out of these reservoirs and extending to selected watercourses in the catchments of the Eucumbene and Snowy Rivers. Boat-based electrofishing surveys were done in Talbingo Reservoir in February 2018 and surveys of fish and aquatic habitat in the Yarrangobilly River Catchment in January/February and May of 2018 were also undertaken to accompany the Snowy 2.0 Exploratory Works Environmental Impact Statement (EMM, 2018), and have been reported therein. Some of these data are also provided here.

The field surveys are summarised in **Table 3-1** and the results described in **Section 5**.

Table 3-1 Summary of aquatic ecology field surveys.

Primary Component	Method	Effort	General Location and Number of Sites or Deployments (if more than one)	Sampling Dates
Talbingo Reservoir				
Fish	Boat-based electrofishing	Approx. 8 hours total on-time	Throughout Reservoir, including Yarrangobilly River and Tumut River arms and various inlets	20 -21 Feb 18
	Gill nets	25 net deployments for approx. 3 hours each (5-28 m depth range)	Plain Creek Bay (5 nets), Cascade Bay (5 nets), Talbingo Spillway/Dam Wall (5 nets), Middle Arm (4 nets), Honeysuckle Bay (2 nets), Glendower Creek (4 nets).	11-13 Sep 18
Fish and crayfish	Bait traps	27 bait traps deployed for approx. 5 hours each	Plain Creek Bay (6 deployments), Cascade Bay (6 deployments), Talbingo Spillway/Dam Wall (3 deployments), Ravine Bay (3 deployments), Middle Arm (9 deployments)	16-17 Jan 19
Crayfish	Hoop nets	130 net deployments (5-58 m depth), minimum 1 hour each	Plain Creek Bay, Cascade Bay, Ravine Bay, Middle Arm, Honeysuckle Bay.	3-5 Oct 18
		18 net deployments (2-20 m depth)	Middle Creek	21 Mar 19
Crayfish	Hoop nets Munyana nets	14 Sites total (20 hoop nets x 3 deployments) 8 (of 14) Sites (Munyana nets)	Throughout reservoir, including Talbingo Boat Ramp, Landers Creek Arm, Lick Hole Creek Arm, O'Hares Campground, Plain Creek Arm,	3-10 Jun 19

Primary Component	Method	Effort	General Location and Number of Sites or Deployments (if more than one)	Sampling Dates
			Honeysuckle Bay, Yarrangobilly River Arm, Middle Creek Arm	
Fish and Crayfish	Multi-species eDNA	12 Sites (3 reps each)	Throughout Reservoir	Feb 18
Aquatic Habitat	Visual inspections	Qualitative	Talbingo Foreshore at location of barge ramps and intake	21-22 Mar 18
Aquatic Habitat and Plants	Towed video/drop camera	67 camera drops (varying number of drops per Location)	Plain Creek Bay, Cascade Bay, Ravine Bay, Middle Arm, Talbingo Spillway/Dam Wall	16-17 Jan 19
	Towed video/drop camera	50 camera drops (varying number of drops per Location)	Middle Creek, Ravine Bay	18-22 Mar 19
Benthic Macroinvertebrates	Van Veen grab	24 replicate grabs (2 replicates per Site, up to 4 Sites per location)	Cascade Bay, Ravine Bay, Talbingo Spillway/Dam Wall,	26-27 Mar 18
	Van Veen grab	10 replicate grabs (2 replicates per Site (up to 2 Sites per location)	Plain Creek Bay, Ravine Bay, Middle Arm	16-17 Jan 19
Phytoplankton	Water sample	15 samples	Throughout reservoir at water quality monitoring locations	20-22 Mar 18
	Water sample	15 samples		25 May 2018
	Water sample	15 samples		6 Jun 18
Tantangara Reservoir				
Fish	Boat-based electrofishing	Approx. 4 hours total on-time	Throughout Reservoir, including Murrumbidgee River and Nungar Creek arms and various inlets	19 Feb 18
	Gill nets	20 net deployments for approx. 3 hours each (1-24 m depth)	Tantangara Mid (6 nets), Tantangara South (8 nets), Upper Murrumbidgee River/Nungar Creek (6 nets)	31 Oct-1 Nov 18
	Bait traps	26 bait traps deployed for approx. 5 hours each	Tantangara Mid (3 deployments), Tantangara South (6 deployments), Upper Murrumbidgee River/Nungar Creek (17 deployments).	27 Mar 18
Crayfish	Hoop nets	92 net deployments (2-23 m depth)	Tantangara South (Intake), Tantangara Mid (Placement Area), Upper Murrumbidgee River/Nungar Creek, North Tantangara	29-30 Oct 18
Visual Inspections, Aquatic Habitat and Plants	Towed video transects	6 x approx. 100 m transects	Proposed Placement area, intake and barge ramp/wharves	1 Nov 18
	Towed video/drop camera	50 camera drops (varying number of drops per Location)	Main reservoir, Murrumbidgee River, Nungar Creek	18-22 Mar 19
Benthic Macroinvertebrates	Van Veen grabs	24 replicate grabs (2 replicates per Site, up to 4 Sites per location)	Tantangara South (Intake), Tantangara Mid (proposed Placement Area), Upper Murrumbidgee River/Nungar Creek	28 Mar 18
		10 replicate grabs (2 replicates per Site (up to 4 Sites per location)	Tantangara South (proposed water Intake & Outlet), Tantangara Mid (proposed Placement Area)	15 Jan 19
Phytoplankton	Water sample	15 samples	Throughout reservoir	20-22 Mar 18
				19 Apr 18
				25 May 18
Fish and Crayfish	Multi-Species eDNA	10 Sites (3 reps at each site)	Throughout Reservoir	Feb 18
	Targeted Species eDNA	13 Sites (4 reps at each site)	Throughout Reservoir	Mar 19
Tumut River Catchment				
T2 Reservoir Catchment				
Fish	Targeted Species eDNA	7 Sites (5 reps at each site)	T2 Reservoir (3 sites), Tumut Pond Reservoir (4 sites)	Mar 19
Upper Tumut Catchment				

Primary Component	Method	Effort	General Location and Number of Sites or Deployments (if more than one)	Sampling Dates
Fish and Crayfish	Multi-Species eDNA	1 Site (3 reps)	O'Hares Creek	Feb 18
	Targeted Species eDNA	2 Sites (3 reps each at each site)	Tumut River	Mar 19
Blowering Reservoir Catchment				
Jounama Pondage	Multi-Species eDNA	4 Sites (3 reps at each site)	Jounama Pondage	Feb 18
Yarrangobilly River Catchment				
Fish and crayfish	Backpack electrofishing	Four x 2 minute shots	Yarrangobilly River (2 sites), Wallace's Creek	29 Jan - 2 Feb 18
Riffle macroinvertebrates	SURBER	4 reps at each of three positions at each site (96 samples total)*	Yarrangobilly River (3 sites), Wallace's Creek	
Aquatic habitat and macrophytes (Inc. identification of KFH)	RCE Visual inspection	50 m upstream and downstream of site	As above plus: Stable Creek, Lick Hole Creek/Gully, Sheep Station Creek, O'Hares Creek	
Targeted galaxiid survey	Backpack electrofishing	13,433 s total on-time (280 s to 3,288 s per site)	Yarrangobilly River (3 sites), Wallace's Creek	2-3 May 18
Fish and crayfish	Backpack electrofishing	8 x 150 s shots per site	Yarrangobilly River (2 sites)	14-18 Jan 19
	Fyke nets	2 to 4 nets set overnight at each site		
	Hoop nets	1-2 set overnight at each site		
	Bait traps	8 deployed overnight at each site		
Aquatic Habitat and Plants (Inc. identification of KFH)	RCE Visual inspection	Approx. 1 km of each creek each side of main alignment		
Fish and Crayfish	Multi-Species eDNA	4 Sites (3 reps at each site)	Yarrangobilly River (2 sites) and Wallaces Creek (2 sites)	Feb 18
Murrumbidgee River Catchment				
Upper Murrumbidgee River Catchment				
Fish and crayfish	Backpack electrofishing	Four x 2 minute shots (480 s on-time)	Gooandra Creek, Mufflers Creek, Kelly's Plain Creek, Tantangara Creek, Upper Murrumbidgee River (2 sites), Nungar Creek	29 Jan - 2 Feb 18
Riffle macroinvertebrates	SURBER	4 reps at each of 3 positions at each site	Gooandra Creek, Tantangara Creek, Murrumbidgee River (2 sites)	
Aquatic habitat and macrophytes (Inc. identification of KFH)	RCE Visual inspection	50 m upstream and downstream of site	As above plus: Ghost Gully, Bally Creek	
Targeted galaxiid survey	Backpack electrofishing	13,433 s total on-time (280 s to 3,288 s per site)	Two watercourses above Tantangara Dam: Tantangara Creek, Upper Murrumbidgee River (2 sites)	2-3 May 18
Fish and crayfish	Backpack electrofishing	8 x 150 s shots per site	Tantangara Creek (2 sites) Gooandra Creek (2 sites) Nungar Creek (2 sites)	3-7 Dec 18
	Fyke nets	2 to 4 nets set overnight at each site		
	Hoop nets	1-2 nets set overnight at each site		

Primary Component	Method	Effort	General Location and Number of Sites or Deployments (if more than one)	Sampling Dates
	Bait traps	8 traps deployed overnight at each site		
Aquatic Habitat and Plants (Inc. identification of KFH)	RCE Visual inspection	Approx. 1 km of each creek either side of main alignment		
Fish and crayfish	Backpack electrofishing	8 x 150 s shots per site	Murrumbidgee River (2 sites)	14-18 Jan 19
	Fyke nets	2 to 4 nets set overnight at each site		
	Hoop nets	1-2 nets set overnight at each site		
	Bait traps	8 traps deployed overnight at each site		
Aquatic Habitat and Plants (Inc. identification of KFH)	RCE Visual inspection	Approx. 1 km of each creek either side of main alignment 50 m upstream and downstream of crossings	As above plus Boggy Plain Creek	
Fish and Crayfish	Multi-Species eDNA	13 Sites (3 reps each site)	Murrumbidgee River (3 sites). Tantangara Creek (2 sites), Gooandra Creek (1 site), Nungar Creek (1 site), Kelly's Plain Creek (2 sites), Mufflers Creek (1 site), Ghost Gully (1 site), Bally Creek (1 site), Goodradigbee River (weir pool) (1 site)	Feb 18
Mid Murrumbidgee River Catchment				
Fish and crayfish	Backpack electrofishing	Four x two minute shots (480 s on-time)	Mid Murrumbidgee River (2 sites)	29 Jan - 2 Feb 18
	Multi-Species eDNA	2 Sites (3 reps at each site)	Murrumbidgee River	Mar 19
	Targeted Species eDNA	8 Sites (3 reps at each site)	Murrumbidgee River (7 sites), Numeralla River (1 site)	Mar 19
Lower Murrumbidgee River Catchment				
Fish and crayfish	Targeted Species eDNA	3 Sites (3 reps at each site)	Murrumbidgee River	Mar 19
Lake Eucumbene Catchment				
Fish and crayfish	Backpack electrofishing	Four x two minute shots (480 s on-time)	Eucumbene River	29 Jan - 2 Feb 18
		8 x 150 s shots per site	Eucumbene River (2 sites)	Mar 19
Aquatic Habitat and Plants (Inc. identification of KFH)	RCE Visual inspection	50 m upstream and downstream of crossings	Eucumbene River, Gang Gang Creek, Chance Creek, Three Mile Creek, Alpine Creek, Rocky Plain Creek	Dec 18 to Jan 19
Fish and Crayfish	Multi-Species eDNA	4 Sites (3 reps at each site)	Eucumbene River (2 sites), Three Mile Creek (1 site), Gang Gang Creek (1 site),	Feb 18
	Targeted Species eDNA	25 Sites (3-4 reps at each site, total 99 samples)	Throughout Lake Eucumbene	Mar 19
Lake Jindabyne Catchment				
Fish	Targeted Species eDNA	21 Sites (4 reps at each site, total 84 samples)	Throughout Lake Jindabyne	Mar 19
Murray River Catchment				
Swampy Plain River Catchment				
Fish	Targeted Species eDNA	5 Sites (3 reps at each site)	Swampy Plain River (2 sites). Khancoban Pondage (2 sites), Bogong Creek (1 site)	Mar 19

Primary Component	Method	Effort	General Location and Number of Sites or Deployments (if more than one)	Sampling Dates
Geehi Reservoir / M2 Reservoir Catchment				
Fish	Targeted Species eDNA	7 Sites (3 to 5 reps at each site)	Geehi Reservoir (4 sites), M2 Reservoir (3 sites)	Mar 19
Murray River Catchment				
Fish	Targeted Species eDNA	1 Site (3 reps at each site)	Swampy Plain River just downstream of Khancoban Dan Wall	Mar 19
Snowy River Catchment				
Lower Snowy River Catchment				
Fish	Targeted Species eDNA	1 Site (4 reps at each site)	Mowamba River Weir Pool	Mar 19

Note: targeted species eDNA surveys: some reservoir sites located in watercourses just upstream of reservoirs.

3.3.2 Methods

3.3.2.1 Aquatic Habitat and Macrophytes

Reservoirs

Aquatic habitat and the distribution of macrophytes (aquatic plants) at a number of locations within Talbingo Reservoir and Tantangara Reservoir were surveyed on 17 January 2019 and 19 March 2019, respectively. The aim was to determine the type and extent of aquatic habitat and macrophytes in areas that have the potential to be impacted as part of the Main works and at reference locations (which are predicted to be unaffected by the Project) (**Figure 3-1** and **Figure 3-2**). Surveys in Talbingo Reservoir focused on the following areas:

> Plain Creek Bay;
> Cascade Bay;
> Ravine Bay;
> Middle Arm; and
> Yarrangobilly River Arm.

Surveys in Tantangara Reservoir focused on proposed works areas including the excavated material and rock placement area, the proposed location of the intake structure and areas not considered to be impacted by project activities.

Surveys were undertaken from a 5 m-long, outboard-powered vessel using an underwater towed video camera and bathyscope. Weather conditions at the time of sampling were good with underwater visibility approximately 3 m to 4 m. At each location, the vessel navigated systematically along transects orientated perpendicular and extending out from the shore. At randomly selected survey points along each transect the camera was lowered to the reservoir bed and the type and density of any macrophytes were recorded and categorised. Each transect was generally traversed from shore to deeper water to allow for depth distributions of macrophytes to be recorded. Some transects could not be completed due to entanglement of the camera and/or its cable on submerged timber. The water depth and GPS coordinates at each survey point were recorded.

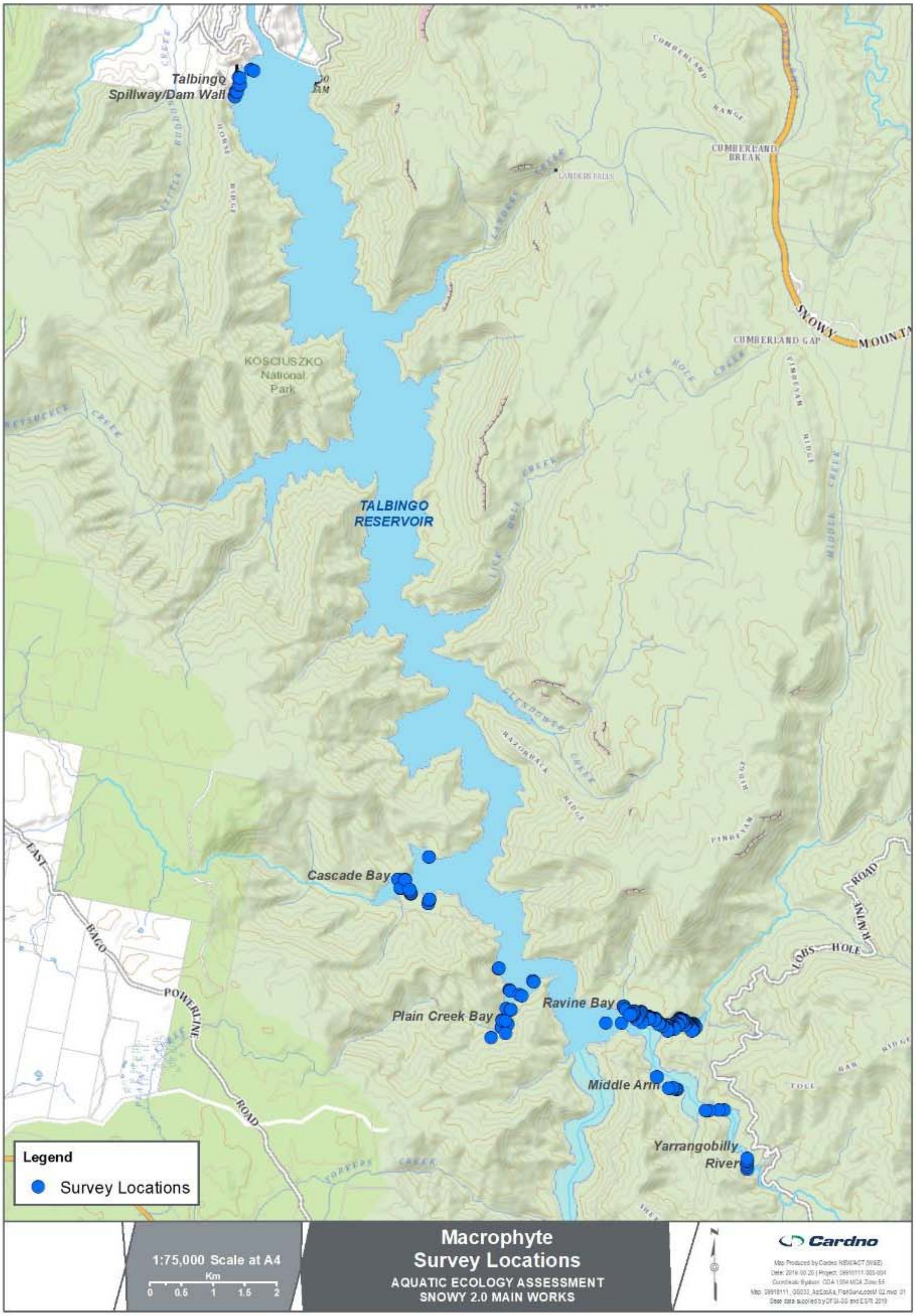


Figure 3-1 Locations sampled for aquatic habitats and macrophytes in Talbingo Reservoir.

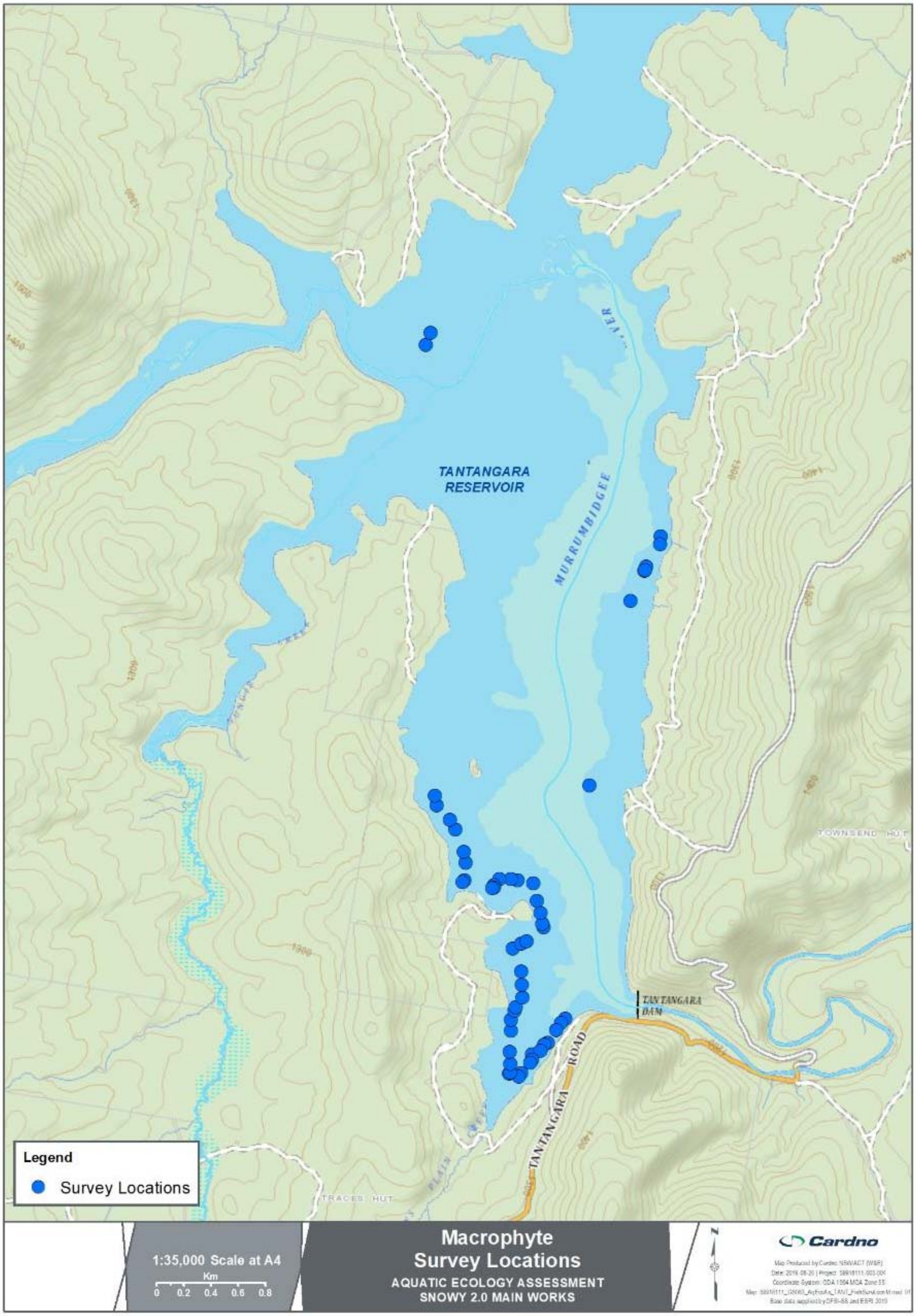


Figure 3-2 Locations sampled for aquatic habitats and macrophytes in Tantangara Reservoir.

Watercourses

The condition of the aquatic habitat was assessed using a modified version of the Riparian, Channel and Environmental Inventory method (RCE) (Chessman et al., 1997) (refer **Attachment B**). This assessment involved evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse and degree of disturbance evident at each site. The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) indicates a heavily channelled stream without any riparian vegetation and can be considered to be in poor condition.

The occurrence of sensitive KFH (including the presence of native aquatic macrophytes, large wood debris, large rocks and/or gravel beds) were noted. Surrounding land uses, condition of riparian vegetation, barriers to fish passage (natural or anthropogenic) and the species of macrophytes were noted at each site. The Class and Type of the watercourse at each site was classified according to NSW DPI (Fisheries) Policy and Guidelines for Fish Habitat Conservation and Management (NSW DPI, 2013a).

Habitat assessments and identifications of aquatic macrophytes were undertaken 50 m either side of each site and crossing location. The primary aim of the habitat assessment undertaken on 3 to 7 December 2018 and 14 to 18 January 2019 was to characterise aquatic habitat, and in particular identify KFH in watercourses of 3rd order and higher (**Figure 3-3**).

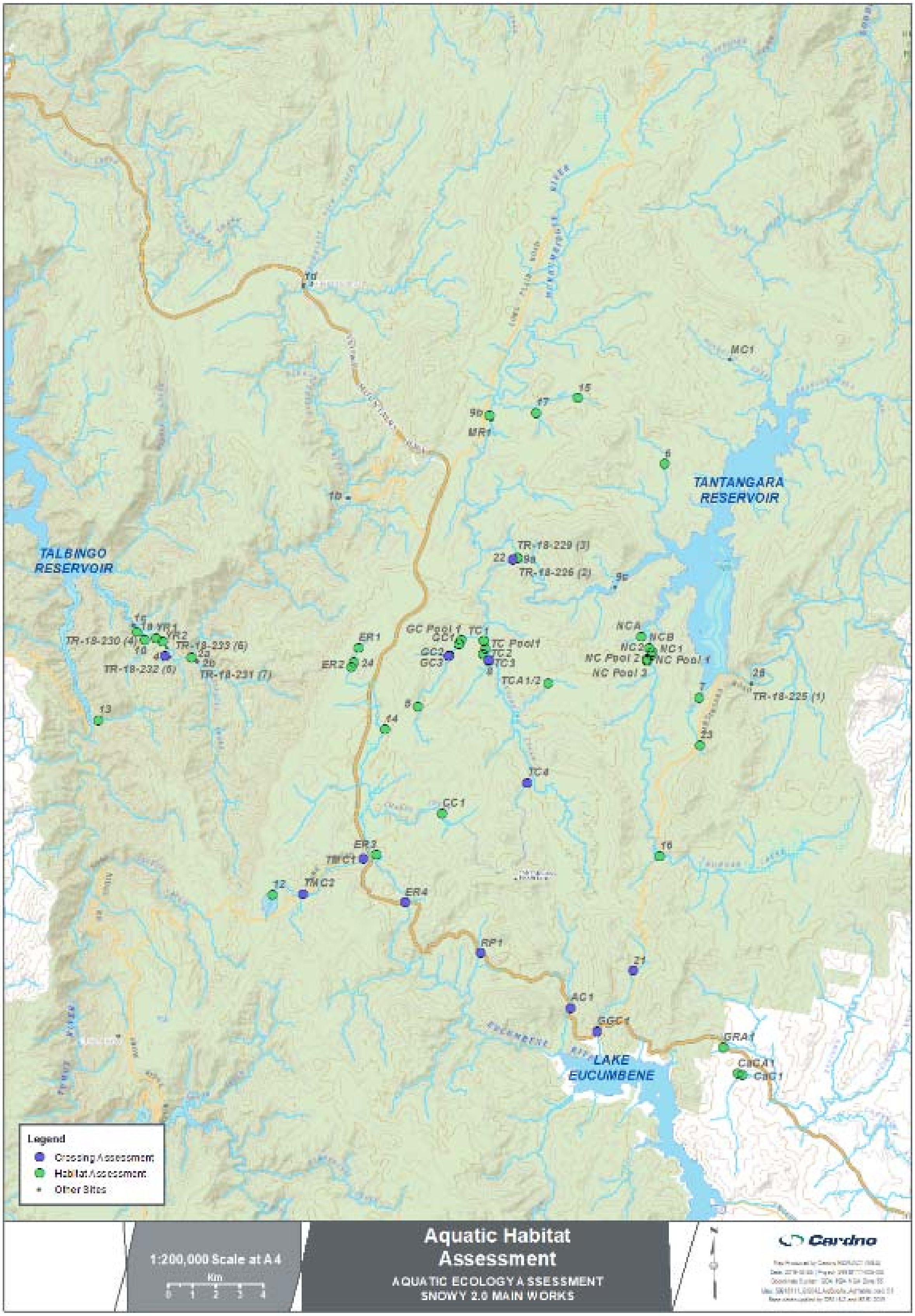


Figure 3-3 Aquatic Habitat Assessment.

3.3.2.2 Fish and Crayfish

Boat-based Electrofishing

Boat-based electrofishing was undertaken in Talbingo Reservoir and Tantangara Reservoir using a Smith Root 7.55 GPP boat mounted electrofisher (**Figure 3-4**). Backpack electrofishing was undertaken in shallower water adjacent to the shoreline in Talbingo Reservoir in the Tumut River (at Sue City near O'Hares Creek), Yarrangobilly River, Middle Creek, Honeysuckle Creek, Lick Hole Creek and Landers Creek arms. Habitats targeted included submerged timber, fallen trees, large rocks and aquatic plants. Electrofishing in Tantangara Reservoir included several locations in the Upper Murrumbidgee River, Nungar Creek, Mosquito Creek arms and other locations along the eastern and western shorelines. The electrofisher was also operated opportunistically whilst travelling between locations in Talbingo and Tantangara reservoirs. The electrofisher was operated for approximately eight hours total on-time over two days in Talbingo Reservoir and four hours total on-time in Tantangara Reservoir.

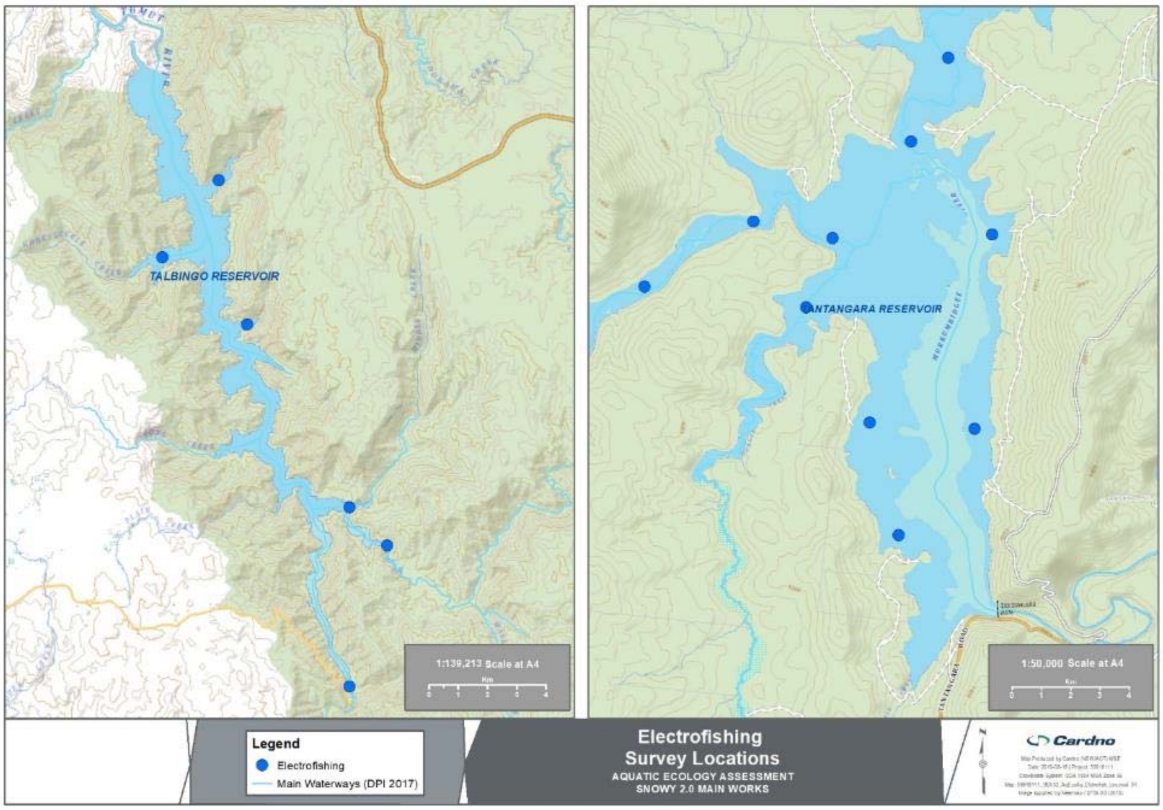


Figure 3-4 Location of boat-based electrofishing surveys in Talbingo Reservoir and Tantangara Reservoir.

Gill Nets

Fish were sampled in Talbingo and Tantangara reservoirs using monofilament nylon gill nets from 11 to 13 September 2018 and 31 October to 1 November 2018, respectively. Gill nets are generally used to sample larger species of fish such as trout and redfin perch in deeper/open water. Each gill net was 50 m long x 1.5 m deep and consisted of two panels with mesh sizes of 65 mm and 35 mm stretched knot to knot. Each net was deployed for approximately three to four hours during daylight hours between 08:30 and 18:00 from a 5.0 m-long vessel. Nets were marked with a float and weighted at each end to enable the setting of nets at various depths. Captured fish were cleared from the net on retrieval, measured (fork length) and counted before being returned to the water. Any pest species captured were euthanized as per NSW DPI guidelines. Gill nets were deployed at the locations identified in **Section 3.3.1** and **Figure 3-5**.

Bait Traps

Collapsible bait traps were deployed in Talbingo Reservoir and Tantangara Reservoir 16 to 17 January 2019 and 15 January 2019, respectively. The traps were 350 mm long, 200 mm wide, 200 m high with an entrance that tapered in to 45 mm, with 3 mm mesh size throughout. Traps were baited with a mixture of wet and dry commercial cat food to attract fish and decapods. Each trap was deployed from a 5.0 m-long vessel for approximately five hours between 9:00 and 18:00 hours. Six traps were also deployed overnight in the Middle Arm and collected the next morning. Bait traps were set on the floor of the waterbody 1 m to 3 m deep to target smaller fish (e.g. eastern gambusia and gudgeons) that are associated with shallow water habitats such as those in and around macrophyte beds, rock bars and timber snags. Any fish captured were cleared from the traps, identified and counted then returned to the water. As with the gill nets, any pest species captured within the bait traps were euthanized as per NSW DPI guidelines. Bait traps were deployed at the locations identified in **Figure 3-5**.

Hoop Nets

Mobile macroinvertebrates were sampled using hoop nets in Talbingo and Tantangara reservoirs from 3 to 5 and 29 to 30 October 2018, respectively. An additional survey was undertaken in Middle Creek within Talbingo Reservoir on 21 March 2019 (**Figure 3-6**). The primary aim of the surveys in the Talbingo Reservoir was to examine the relative abundance and distribution of Murray crayfish there. Sampling was undertaken using baited (ox liver) single hoop nets, following the method used previously in Talbingo Reservoir by Zukowski, et al., (2013). Each net was 700 mm in diameter with a mesh size of 13 mm. Where possible, three depth strata (0-10 m, 10-20 m, 20-30 m) at each sampling location were sampled with the intent of examining relative abundance of mobile macroinvertebrates among these depth strata. Each net was set for approximately one hour.

Decapods captured were cleared from the nets on retrieval and examined for the following characteristics:

- Occipital Carapace Length (mm) (OCL), measured from the rear of the eye socket to the middle of the rear of the carapace);
- Sex;
- The maturity stage of adult females (stages 1-3) based on Turvey and Merrick 1997); and
- Presence of females in berry (carrying eggs).

All decapods were released after examination.

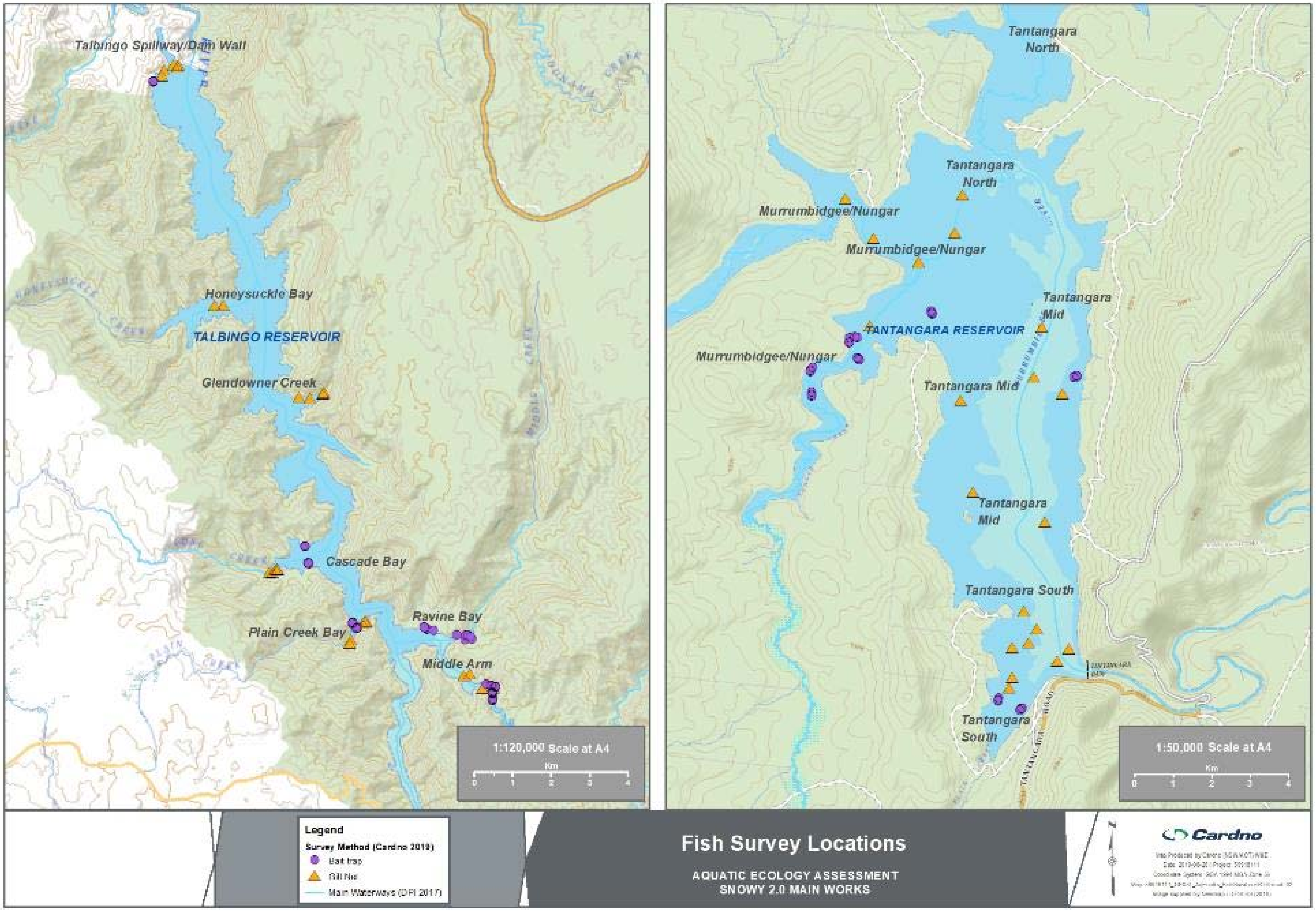


Figure 3-5 Location of gill net and bait trap deployments in Talbingo Reservoir and Tantangara Reservoir.

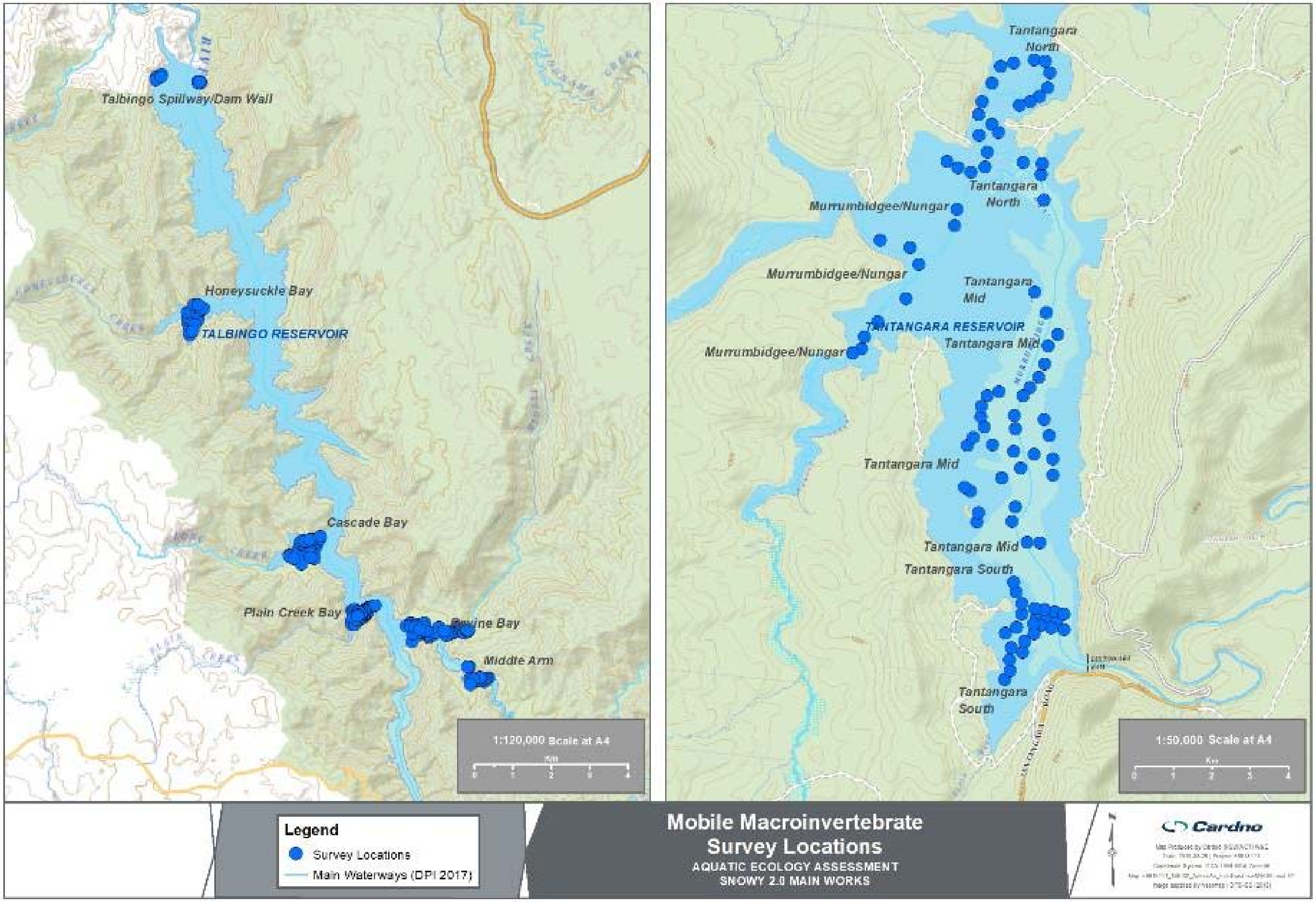


Figure 3-6 Location of hoop net deployments used to sample decapods in Talbingo and Tantangara reservoirs.

Watercourses

Details of watercourse survey methodology and sites sampled are in **Table 3-2.**

Table 3-2 Watercourse Survey Site Information. Datum for GPS coordinates WGS84.

Watercourse	Site	Latitude	Longitude	Date	Method and Effort					
					Aquatic Habitat & Plants /	Electrofishing	Fyke Nets	Bait Traps	Hoop Nets	SURBER
Yarrangobilly River Catchment										
Yarrangobilly River	1a	-35.783	148.387	Jan/Feb 18	Y	BE (480 s)				S (12)
	1b	-35.731	148.484	Jan/Feb 18		BE (480 s)				S (12)
	1c	-35.781	148.386	Feb 18		BBE				
	1d	-35.651	148.462	Jan/Feb 18						S (12)
	YR1	-35.785	148.396	Jan 19	Y	BE (1200 s)	FN (2)	BT (8)	HN (2)	
	YR2	-35.787	148.399	Jan 19	Y	BE (1200 s)	FN (2)	BT (8)	HN (2)	
	TR-18-230 (4)	-35.785	148.390	May 18		BE (1873 s)				
	TR-18-232 (5)	-35.793	148.403	May 18		BE (1825 s)				
	TR-18-233 (6)	-35.789	148.401	May 18		BE (1880 s)				
Wallace's Creek	2a	-35.792	148.412	Jan/Feb 18	Y	BE (480 s)				
	2b	-35.794	148.415	Jan/Feb 18						S (12)
	TR-18-231 (7)	-35.792	148.412	May 19		BE (1201 s)				
Lick Hole Creek	4	-35.792	148.400	Jan/Feb 18	Y					
Sheep Station Creek	10	-35.786	148.391	Jan/Feb 18	Y					
O'Hare's Creek	13	-35.817	148.369	Jan/Feb 18	Y	BE (480 s)				
Upper Murrumbidgee River Catchment										
Upper Murrumbidgee River	9a	-35.753	148.564	Jan/Feb 18	Y	BE (480 s)				S (12)
	9a	-35.753	148.564	Dec 18		BE (1200 s)				
	9a	-35.753	148.564	Mar 19		BE (600 s)				
	9b	-35.699	148.550	Jan/Feb 18	Y	BE (480 s)				S (12)
	9b	-35.699	148.550	Jan 19		BE (1200 s)	FN (3)	BT (8)	HN (2)	
	9c	-35.763	148.609	Feb 18		BE (1200+ s)				
	MR1	-35.701	148.551	Jan 19		BE (1200 s)	FN (3)	BT (8)	HN (2)	
	TR-18-226 (2)	-35.754	148.564	May 18		BE (3288 s)				
Tantangara Creek	8	-35.792	148.551	Jan/Feb 18	Y	BE (480 s)				S (12)
	22	-35.754	148.561	Jan/Feb 18	Y					
	TC1	-35.785	148.549	Dec 18	Y	BE (1200 s)	FN (4)	BT (8)		
	TC1	-35.785	148.549	Mar 19		BE (1200 s)				
	TC2	-35.790	148.548	Dec 18	Y	BE (1200 s)	FN (3)	BT (8)		
	TC2	-35.790	148.548	Mar 19		BE (1200 s)				
	TC3	-35.792	148.551	Dec 18	Y					
	TC4	-35.838	148.57	Dec 19	Y					
	TCA1/2	-35.800	148.579	Dec 18	Y	BE (1200 s)	FN (2)	BT (8)		

Watercourse	Site	Latitude	Longitude	Date	Method and Effort					
					Aquatic Habitat & Plants /	Electrofishing	Fyke Nets	Bait Traps	Hoop Nets	SURBER
	TR-18-229 (3)	-35.752	148.563	Mar 19		BE (1200 s)				
	TC Pool1	-35.787	148.549	Dec 18	Y	BF (150 s)			HN (2)	
Gooandra Creek	5	-35.810	148.518	Jan/Feb 18	Y	BE (480 s)				S (12)
	GC Pool 1	-35.784	148.538	Dec 18	Y	BE (150 s)		BT (8)	HN (2)	
	GC1	-35.786	148.537	Dec 18	Y	BE (1200 s)	FN (2)	BT (8)		
	GC2	-35.790	148.533	Dec 18	Y	BE (1200 s)	FN (2)	BT (8)		
	GC3	-35.791	148.532	Dec 18	Y					
Nungar Creek	16	-35.865	148.632	Jan/Feb 18	Y	BE (480 s)				
	NC North Tributary	-35.782	148.622	Dec 18	Y					
	NC Southern Tributary	-35.786	148.626	Dec 18	Y					
	NC Pool 1	-35.791	148.625	Dec 18	Y	BF (150 s)		BT (4)	HN (2)	
	NC Pool 2	-35.791	148.625	Dec 18	Y	BF (150 s)		BT (4)	HN (2)	
	NC Pool 3	-35.791	148.625	Dec 18	Y	BF (150 s)		BT (4)	HN (2)	
	NC1	-35.788	148.627	Dec 18	Y	BE (1200 s)	FN (2)	BT (8)		
	NC2	-35.789	148.627	Dec 18	Y	BE (1200 s)	FN (2)	BT (8)		
Mufflers Creek	6	-35.716	148.631	Jan/Feb 18	Y	BE (480 s)				
Kelly's Plain Creek (d/s)	7	-35.805	148.649	Jan/Feb 18	Y	BE (480 s)				
Kelly's Plain Creek (u/s)	23	649091	603438	Jan/Feb 18	Y					
Ghost Gully	15	-35.692	148.590	Jan/Feb 18	Y	BE (480 s)				
Bally Creek	17	-35.698	148.571	Jan/Feb 18	Y					
Mosquito Creek	MC1	-35.677	148.661	Mar 19		BE (1200 s)				
Upper Eucumbene River Catchment										
Eucumbene River	14	-35.819	148.503	Jan/Feb 18	Y	BE (480 s)				
	24	-35.794	148.488	Jan/Feb 18	Y					
	ER1	-35.788	148.490	Mar 19	Y	BE (1200 s)				
	ER2	-35.795	148.487	Mar 19	Y	BE (1200 s)				
	ER3	-35.866	148.500	Mar 19			FN (4)	BT (8)	HN (2)	S (6)
	ER4	-35.884	148.514	Jan 19	Y					
Gang Gang Creek	21	-35.909	148.621	Jan/Feb 18						
	GGC1	-35.932	148.604	Dec 18	Y					
Three Mile Creek	12	-35.882	148.452	Jan/Feb 18	Y					
	TMC1	-35.868	148.494	Dec 18	Y					
	TMC2	-35.881	148.466	Dec 18	Y					
Chance Creek	CC1	-35.850	148.530	Jan 19	Y					
Alpine Creek	AP1	-35.923	148.592	Dec 18	Y					
Rocky Plain Creek	RP1	-35.903	148.549	Dec 18	Y					
Mid-Murrumbidgee River Catchment										
Mid-Murrumbidgee River - (d/s)	25	-35.799	148.674	Jan/Feb 18		BE (480 s)				

Watercourse	Site	Latitude	Longitude	Date	Method and Effort					
					Aquatic Habitat & Plants /	Electrofishing	Fyke Nets	Bait Traps	Hoop Nets	SURBER
Tantangara Reservoir dam wall)	TR-18-225 (1)	-35.799	148.674	May 18		BE (3086 s)				
Goodradigbee River Weirpool	26	-35.664	148.751	Jan/Feb 18		BE (480 s)				
Camerons Creek	CC1	-35.948	148.672	Mar 18	Y					
Camerons Creek Tributary	CCA1	-35.947	148.670	Mar 18	Y					
Goorudee Rivulet Tributary	GRA1	-35.937	148.663	Mar 18	Y					
Cooma Creek Tributary	CoCA1	-36.235	149.149	Mar 18	Y					

Backpack Electrofishing

A backpack electrofisher (model LR-24 Smith-Root) was operated in a variety of aquatic habitats including pool edges, riffles, and amongst aquatic plants and woody debris (**Figure 3-7**). Stunned fish were collected in a scoop net, identified and measured. All captured fish were handled with care to minimise stress, and released as soon as possible with the exception of pest species that were euthanized in accordance with Cardno's scientific collection permit. Specimens of galaxiids caught from the Yarrangobilly River Catchment (two specimens), Upper Murrumbidgee River Catchment (15 specimens) and Mid Murrumbidgee River Catchment (15 specimens) in May 2018 were retained for detailed morphological examination (Raadik, 2018). Sampling was undertaken with consideration of the Australian Code of Electrofishing Practice (NSW Fisheries 1997), including the presence of an experienced electrofishing operator at all times. During the 29 January to 2 February 2018 field survey, the method involved four 120 second shots (480 seconds total operation on time) over approximately 200 m of watercourse length at each site. During 3 to 7 December 2018 and 14 to 18 January 2019 eight 150 s shots (1,200 seconds total operation time) were undertaken over approximately 1 km of watercourse length at each site.

Fyke Nets

Two to four fyke nets were set overnight in deeper pools and near undercut banks and aquatic plants, if present (**Figure 3-8**). Fyke nets were a mixture of single and double wing, 0.4 to 0.8 m diameter entrance and approximately 9 mm mesh. The nets were set so that the entrance was submerged whilst also allowing a breathing space to be maintained in the net for air breathing animals (such as platypus and turtles).

Bait Traps

Eight collapsible bait traps (approximately twenty 40 cm, 3 mm mesh, 3 cm opening) baited with dried cat food were deployed overnight in watercourses and in nearby disconnected pools, targeting deeper water that could not be accessed by backpack electrofishing (**Figure 3-9**).

Hoop Nets

Two to four hoop nets the same as those deployed in the reservoirs were set overnight in deeper pools within the watercourses or nearby disconnected pools (**Figure 3-10**).

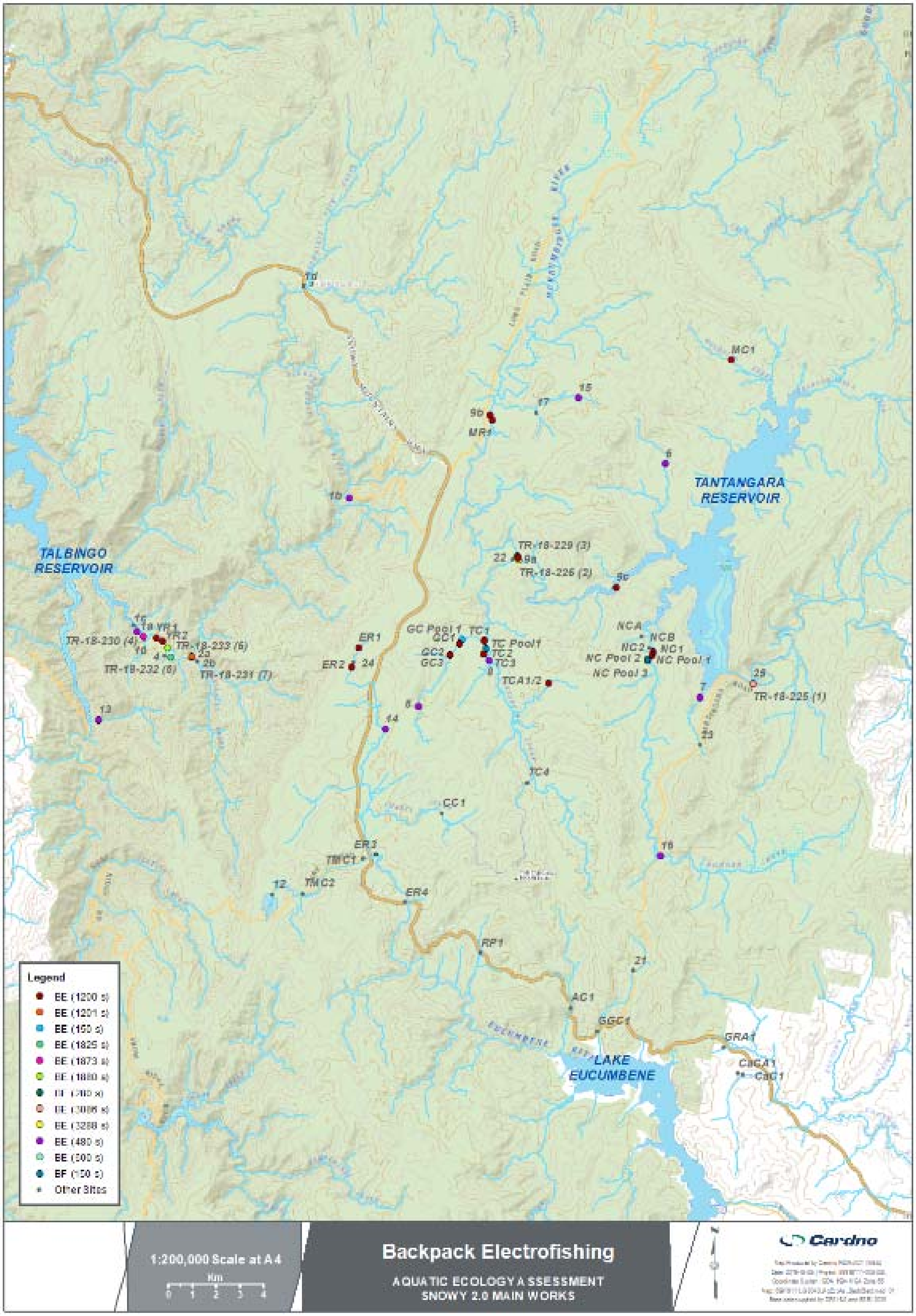


Figure 3-7 Backpack electrofishing locations (effort in seconds of operation).

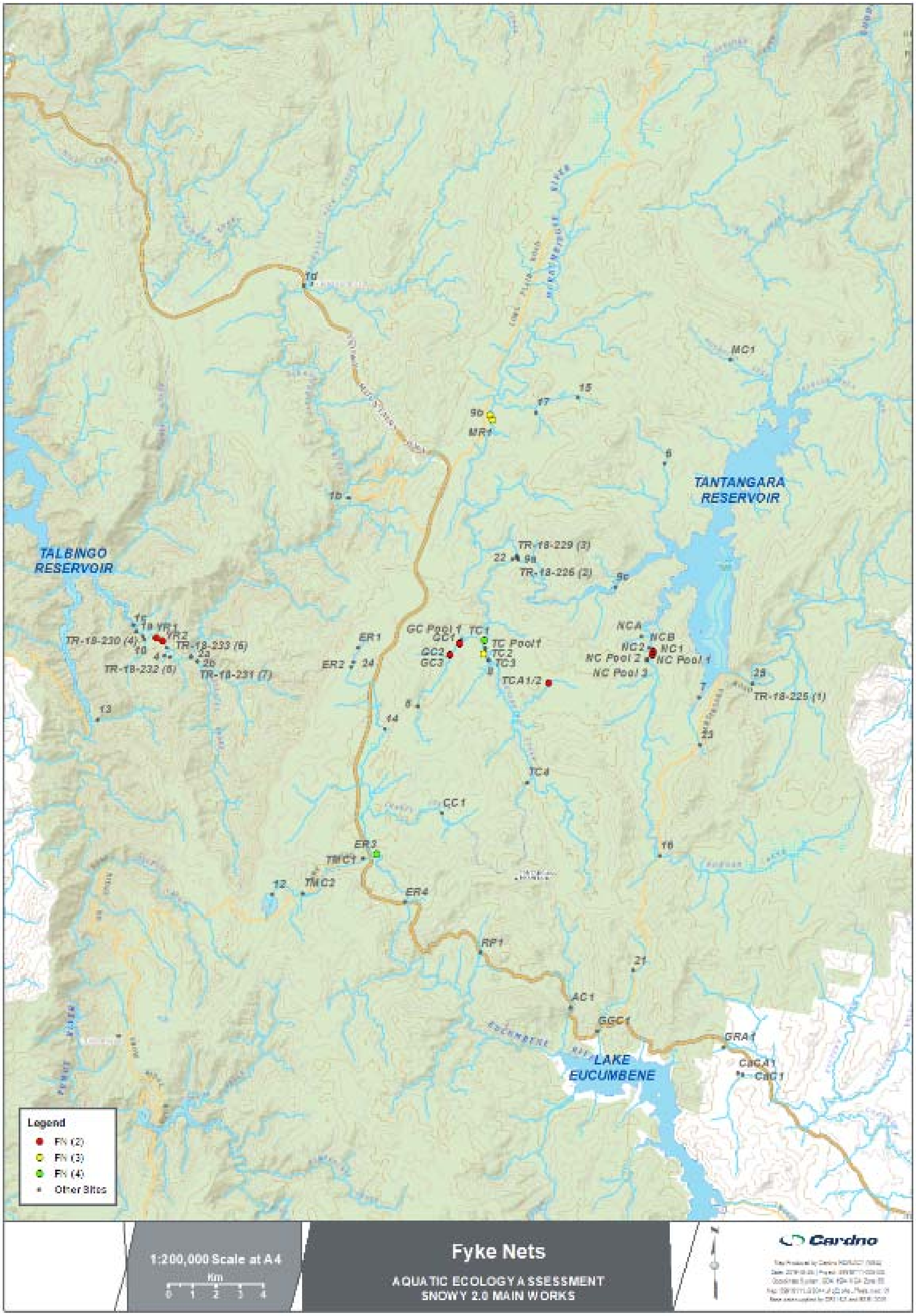


Figure 3-8 Fyke net locations (effort in number of deployments).

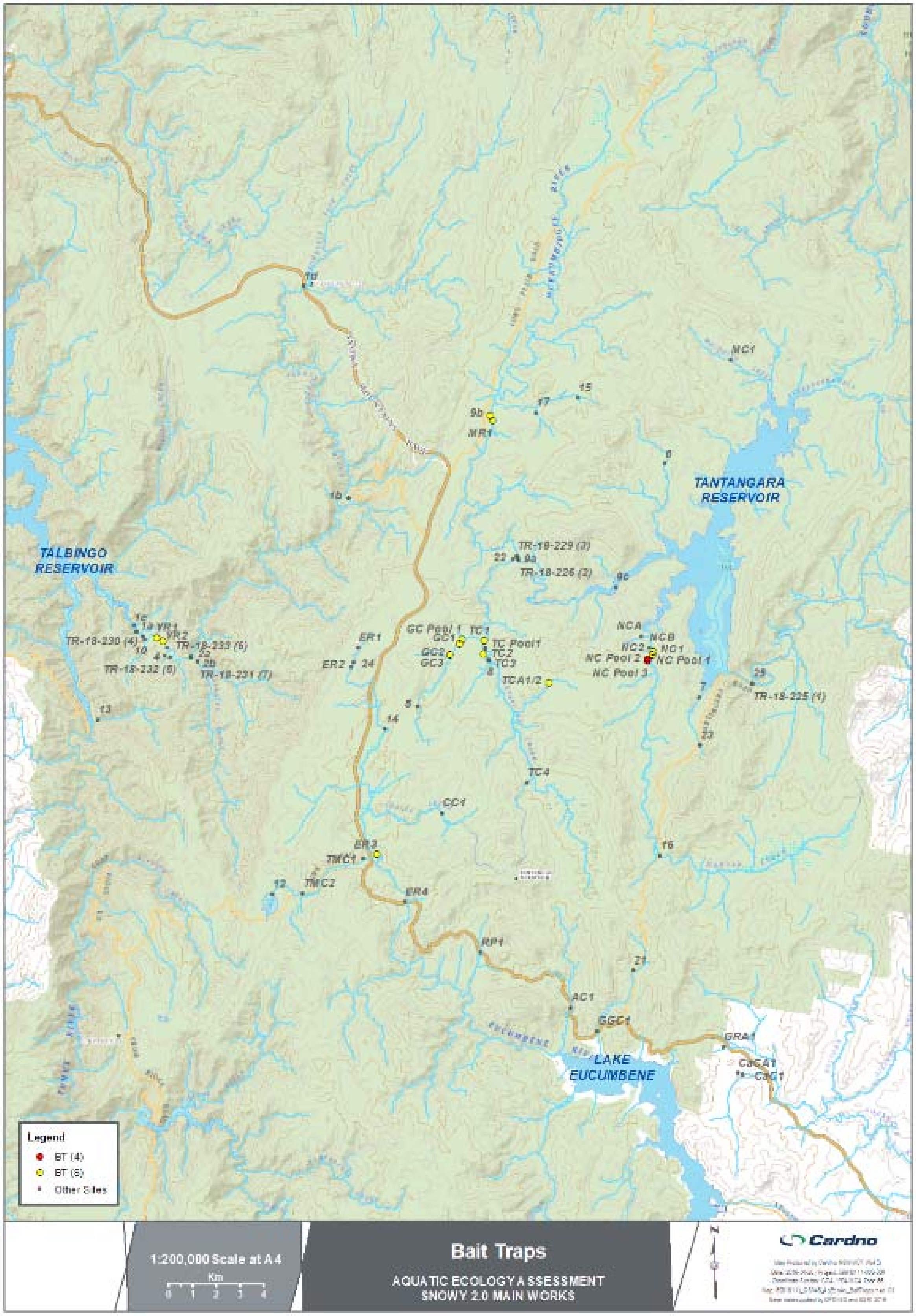


Figure 3-9 Bait trap locations (effort in number of deployments).

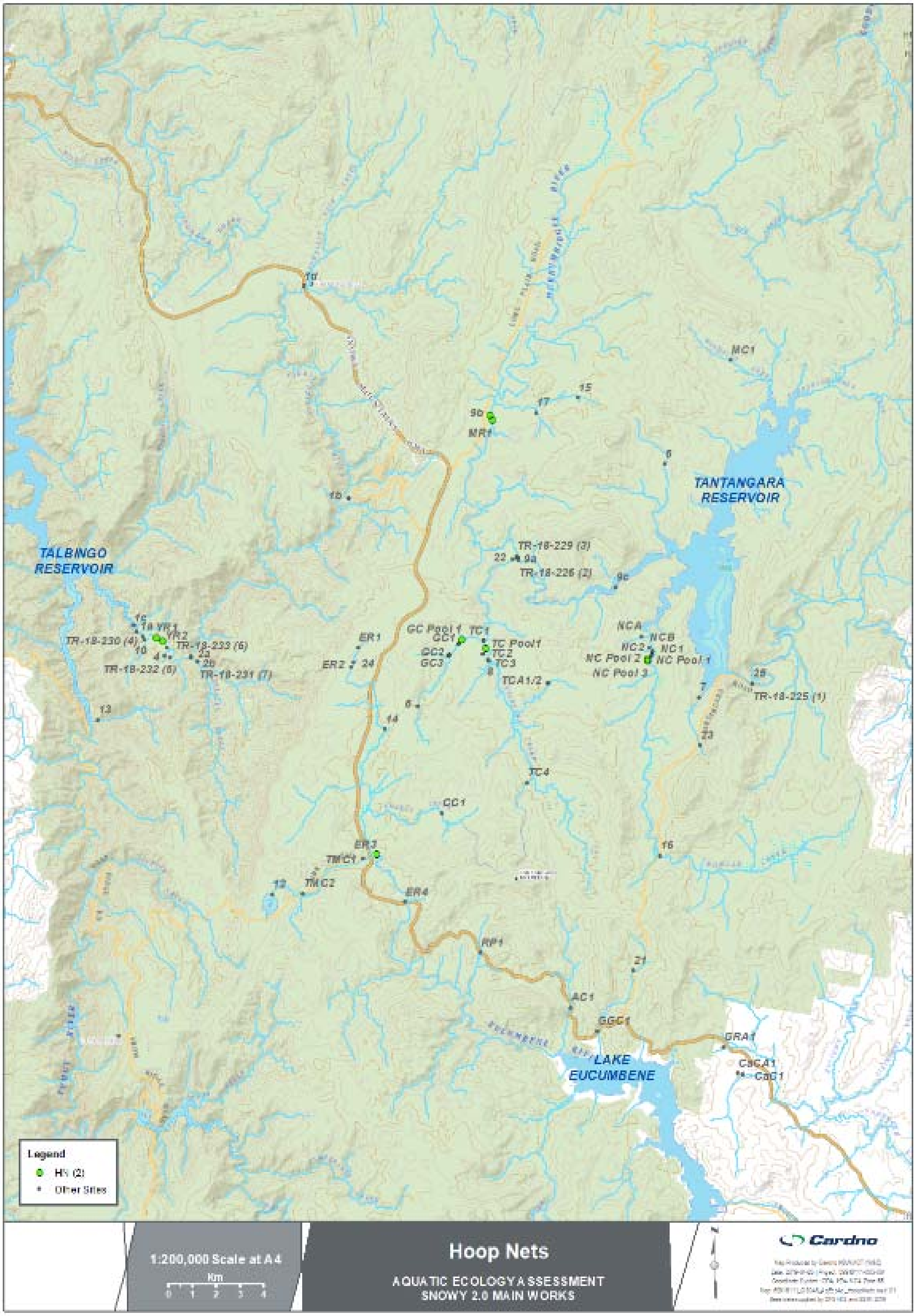


Figure 3-10 Hoop net locations (effort in number of deployments).

3.3.2.3 eDNA

Two types of eDNA sampling was undertaken as part of this project. The first involved the use of a metabarcoding approach that sought to identify all fish and decapod species that may be present in the sampling locations. The second approach involved the use of single species assays where samples were screened for the presence or absence of DNA material corresponding to particular species. EnviroDNA Pty Ltd was engaged to collect water samples and implement eDNA metabarcoding techniques to investigate the presence of fish and decapods in Talbingo Reservoir, Tantangara Reservoir and selected watercourses in the study area in February 2018 using standardised techniques (EnviroDNA, 2019a). Water samples were used to extract DNA from sampling sites to complement other methods such as electrofishing and netting. It is a non-invasive sampling technique that detects genetic material from a target species secreted into its surrounding environment (i.e. water).

For the metabarcoding study, water samples were collected and filtered with samples then being transported to the laboratory where DNA was extracted. At each site, triplicate water samples were collected and filtered in the field. Biodiversity assessments were performed with two separate metabarcoding assays - a universal fish and universal decapod crustacean assay. DNA sequence reads were clustered into Operational Taxonomic Units (OTUs) based on DNA sequence similarity (identity cut-off threshold = 98% fish, 99% decapods). Each OTU was assigned a species identity by comparing with a custom fish and decapod reference sequence database containing data for native and introduced species occurring within south-eastern Australia. One representative DNA sequence was selected per OTU and searched against all DNA sequences in the reference database. Matches to the database were recorded using a step-wise process that was designed to maximise the accuracy of species assignment, while allowing for some within species variability (EnviroDNA, 2019a). Once DNA had been assigned, the abundance of that DNA was reported relative to the abundance of DNA assigned to other fish or decapods in the sample of water at each site (averaged across triplicates). The sites sampled by EnviroDNA (2019a) generally aligned with the backpack and boat-based electrofishing sites in watercourses and reservoirs, respectively (**Section 3.3.2.2**), though DNA samples were collected at additional sites spread throughout each reservoir. The water sample collected from Site 13 was also collected from the confluence of the creek with Talbingo Reservoir, whereas the watercourse survey was undertaken a few hundred metres further upstream.

EnviroDNA Pty Ltd was also engaged to investigate the distribution of redfin perch, eastern gambusia, Macquarie perch and climbing galaxias at selected locations within the Tumut River, Murrumbidgee River and Snowy River catchments in March 2019 (EnviroDNA 2019b);

> Lake Eucumbene;

> Tumut Pond Reservoir;

> T2 Dam;

> Geehi Reservoir;

> M2 Dam;

> Jindabyne Reservoir;

> Tantangara Reservoir;

> Selected river sites between reservoirs; and,

> Upper Murrumbidgee River below Tantangara Dam.

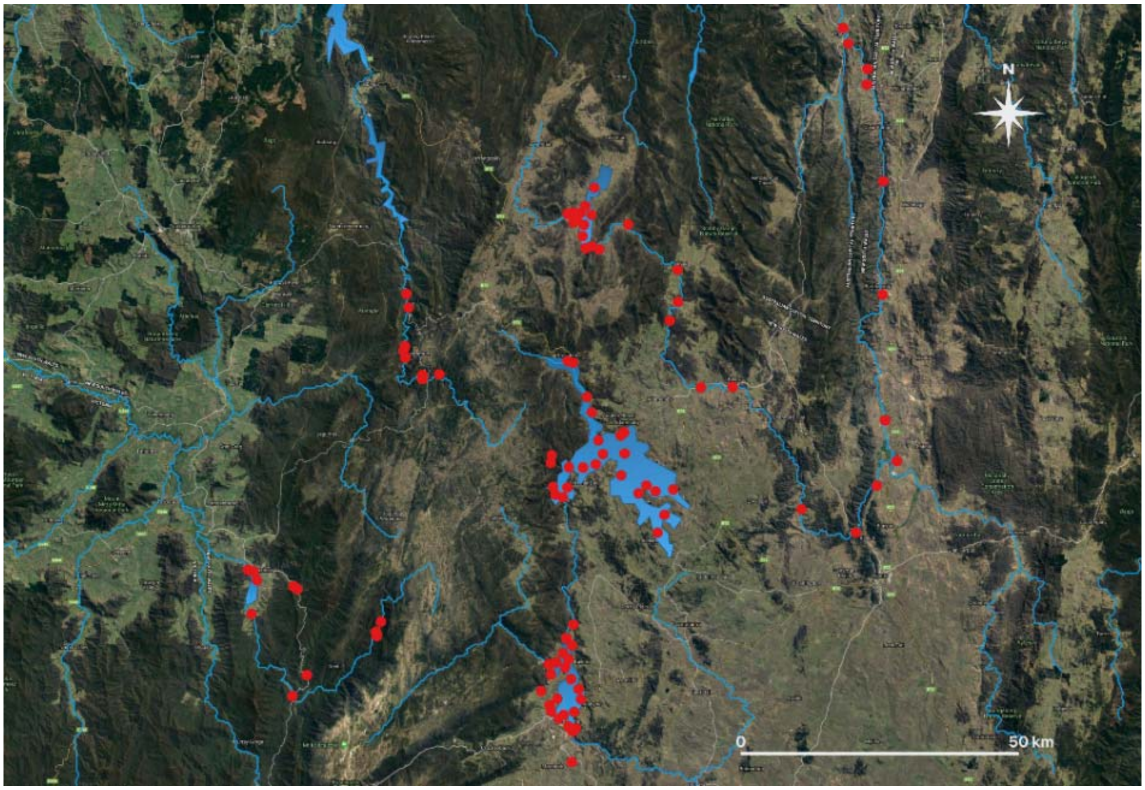


Figure 3-11 Location of EnviroDNA (2019b) targeted species sampling sites

A previous study examining the occurrence of redfin perch in Tantangara Reservoir was undertaken in 2017, with no redfin perch DNA detected. For the targeted species surveys, water samples from each site (three to five replicates at each, with each replicate split into triplicate in the laboratory for quantitative PCR (qPCR)) were assessed for the presence of redfin perch and eastern gambusia DNA. The presence of Macquarie perch DNA was assessed in samples from Mid Murrumbidgee River Catchment sites. Climbing galaxias DNA was assessed at all sites in Tantangara Reservoir, a selection of sites from Lake Eucumbene and one site from each of Lake Jindabyne, Geehi Reservoir and M2 Reservoir and all sites in the Mid Murrumbidgee River Catchment.

Two sources of uncertainty can arise with environmental DNA studies: first, uncertainty regarding the origin and the identity of the DNA. DNA in an area may originate from live individuals in the area or may represent contamination from other nearby areas (e.g. transfer or DNA via human or animal vectors) or within the laboratory. Where DNA is detected in relatively low abundance in a sample and / or in relatively small proportion of all sites sampled within an area (e.g. a watercourse or large waterbody) there is less certainty that the DNA originated from, and represents, live individuals in that area. As a guide to assist with interpretation of these data, EnviroDNA (EnviroDNA, 2019a) considered that DNA detections at 1 % and lower relative abundance provided relatively low confidence that live individuals were present. EnviroDNA (2019b) considered that DNA detected in 2 or less qPCRs samples as an ‘equivocal’ detection of live individuals and that DNA detected in 3 or more qPCR samples as a ‘positive’ detection of live individuals.

Second, uncertainty in the multi-species approach can arise when OTUs are not able to be assigned adequately to a species in the reference sequence database. This may be due to insufficient reference material, particularly when species are closely related. In such circumstances, the taxonomic resolution is reduced and the DNA detections reported at a taxonomic level at which there is sufficient confidence (e.g. at Family rather than Species level).

3.3.2.4 Benthic Marcoinvertebrates

Benthic macroinvertebrates were sampled using a van veen grab in Talbingo Reservoir on 26 and 27 March 2018 and 16 January 2019; and in Tantangara Reservoir on 28 March 2018 and 15 January 2019. The aim was to characterise the diversity and abundance of macroinvertebrate assemblages associated with soft sediment habitat in the reservoirs. Surveys in March 2018 were undertaken to collect information on benthic invertebrates broadly throughout each reservoir. Those undertaken in January 2019 focussed on key project areas (e.g. construction and dredging locations).

Talbingo Reservoir was sampled as follows:

> March 2018 survey:
  - Ravine Bay/Tumut River (2 replicate grabs within 4 sites);
  - Cascade Bay (2 replicate grabs within each of 4 sites);
  - Main Reservoir – Mid (2 replicate grabs at 1 site);
  - Main Reservoir – North (2 replicate grabs within each of 2 sites); and
  - Dam Wall (2 replicate grabs at 1 site).
> January 2019 survey:
  - Plain Creek Bay (2 replicate grabs within each of 2 Sites);
  - Ravine Bay (2 replicate grabs within 1 Site); and
  - Middle Arm (2 replicate grabs within each of 2 Sites).

Tantangara Reservoir was sampled as follows:

> March 2018 survey:
  - Tantangara South (2 replicate grabs within 4 sites);
  - Tantangara Mid (2 replicate grabs within 4 sites); and
  - Murrumbidgee River (2 replicate grabs within 4 sites).
> January 2019 survey:
  - Tantangara South (2 replicate grabs within 1 site); and
  - Tantangara Mid (2 replicate grabs within 4 sites).

This yielded a total of 24 samples from March 2018 and 10 samples from January 2019 from each of the reservoirs. Sampling sites are shown in **Figure 3-12**.

The van veen sediment grab was deployed from a small survey vessel – lowered to the bottom and winch back to the boat. Samples were sieved through a 0.5 mm mesh and the retained sediment and biota transferred to a labelled bag, preserved with dilute formalin (~ 7%) and stained (Rose Bengal). Samples were transported to Cardno's Sydney laboratory where they were rinsed of formalin (following a minimum of 24 hrs to ensure fixation) and transferred to ethanol for preservation and storage. Animals were removed from each sample under a binocular microscope (x 40 magnification) and sorted into major taxonomic groups before being counted and identified to family-level where possible. Major groups such as oligochaetes or nematodes were identified to sub-class or Phylum as any identification to a finer taxonomic resolution involves significant investment of time and resources for these taxa (e.g. examination of internal anatomy). A reference collection of representative taxa was compiled and stored.

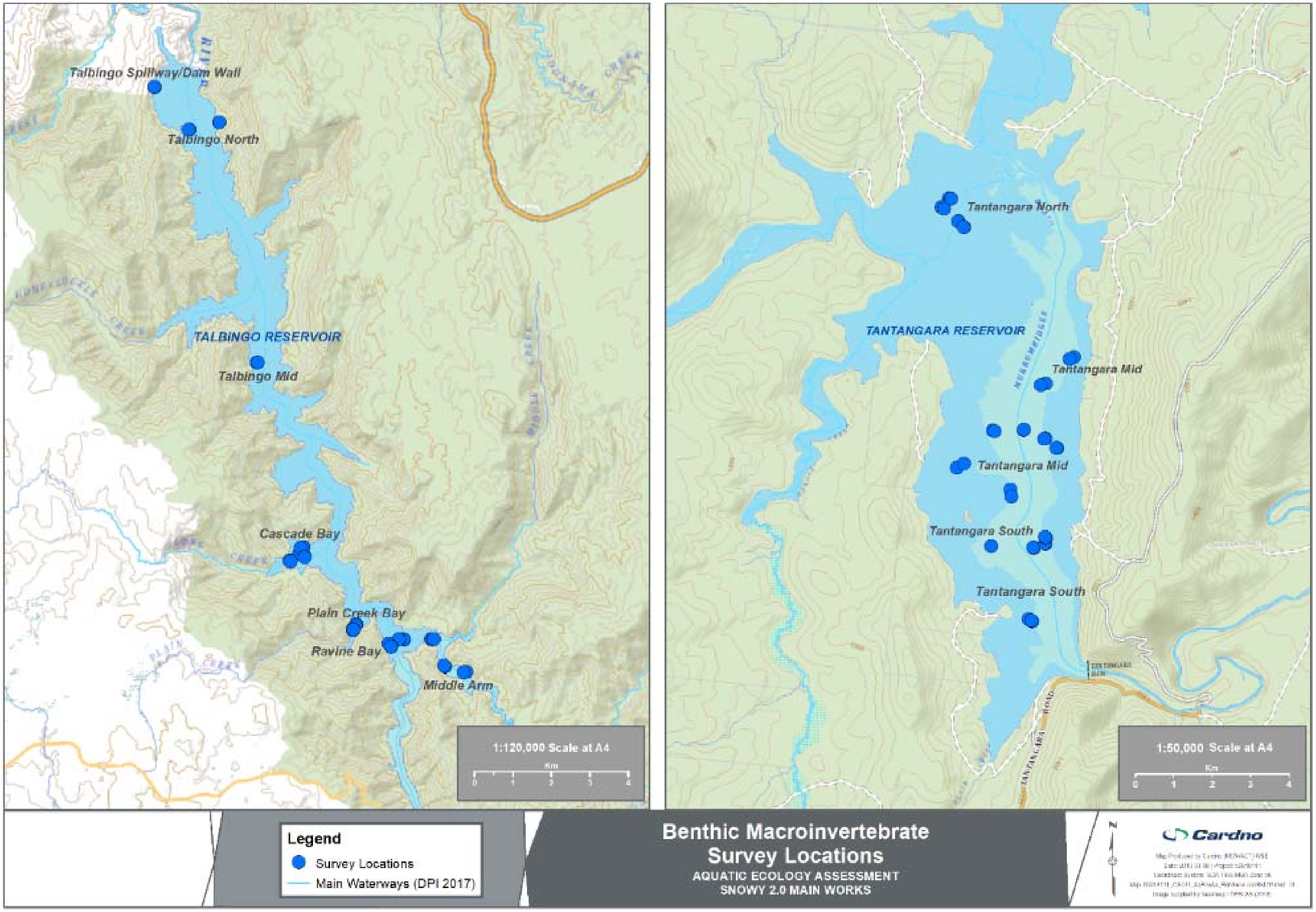


Figure 3-12 Location of benthic infauna sample sites in Talbingo and Tantangara reservoirs.

3.3.2.5 Riffle macroinvertebrates

Four replicate samples from each of three positions within the riffle habitat at watercourse sites (**Figure 3-13**) were collected by placing a SURBER sampler (0.29 m^2 quadrat, 250 µm mesh) facing upstream and vigorously agitating the substratum enclosed within the quadrat for a period of two minutes per replicate. Agitation was effected by the collector, who rubbed around the surfaces of the rocks and amongst the sediments between and under the rocks. After two minutes, the net was submerged frequently with care to allow the sediment to accumulate in the bottom of the net. The net was then inverted and its contents rinsed into a labelled plastic bag with ethanol as a preservative and returned to Cardno's Sydney laboratory.

Macroinvertebrates were identified to Family under a binocular microscope at x40 magnification and each specimen counted. Any freshwater crayfish that had been removed during the sub-sampling process were included in specimen counts on the datasheets and then released. All identified macroinvertebrates were archived, with individual taxa stored separately in 70% ethanol. Ten percent of sample identifications were cross-checked.

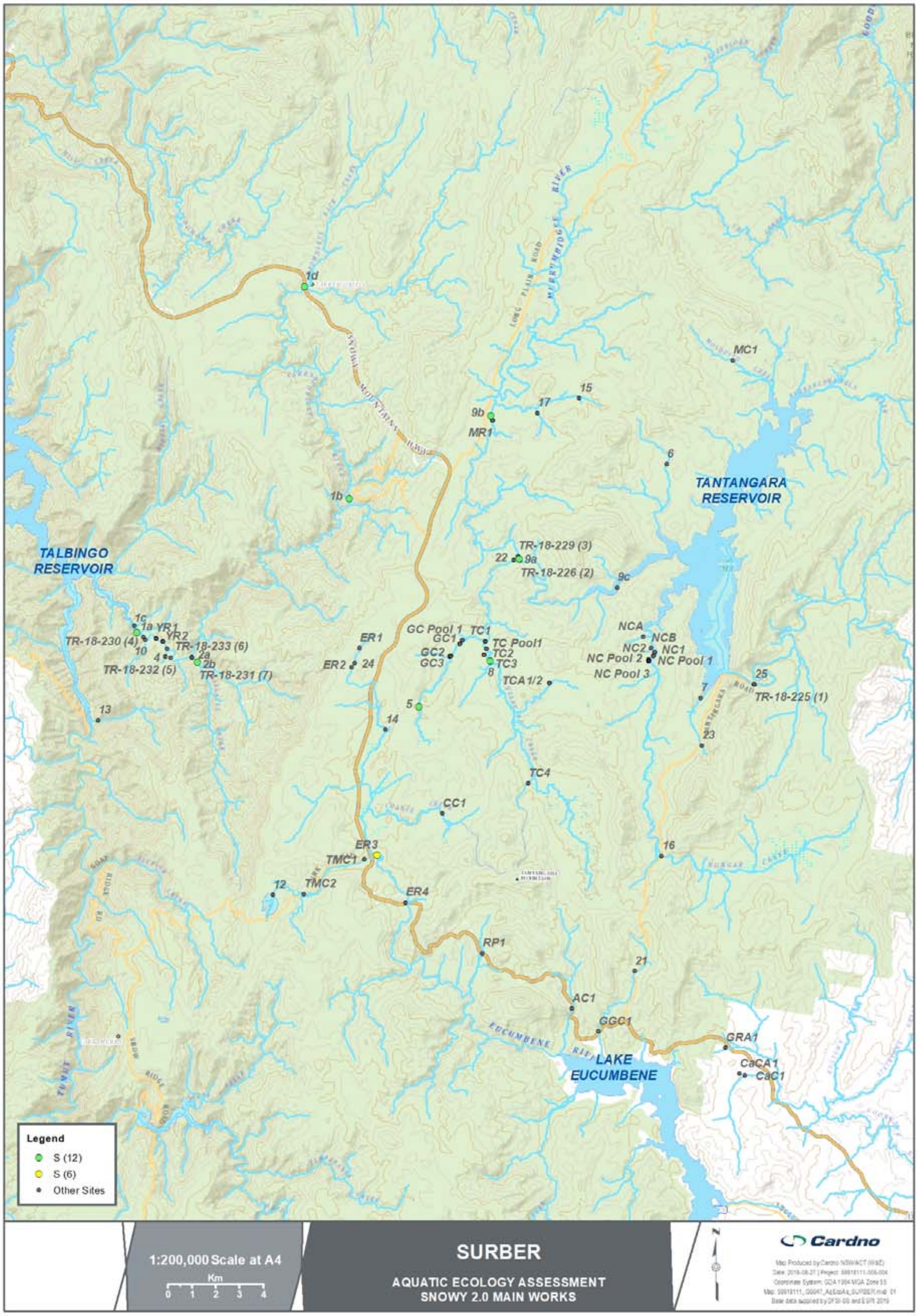


Figure 3-13 SURBER sample sites.

3.3.2.6 Phytoplankton

Water samples were collected from each reservoir for characterisation of phytoplankton assemblages as follows:

> Talbingo Reservoir: March, May, June 2018; and
> Tantangara Reservoir: March, April, May 2018.

Three replicate samples were collected by towing a plankton net from a 5.5 m long, outboard-powered boat at each location (**Figure 3-14**) within the upper 3 m of the water column.

While the sampling design was developed originally to inform predictions regarding changes in algal biomass that may occur due to operation of the project, the findings also provide some insight into differences in the composition of the phytoplankton assemblage between the two reservoirs, complementing the data available from longer-term sampling (**Section 3.2.3**). Cardno's study, however, adopted a greater taxonomic resolution than most of the historical data.

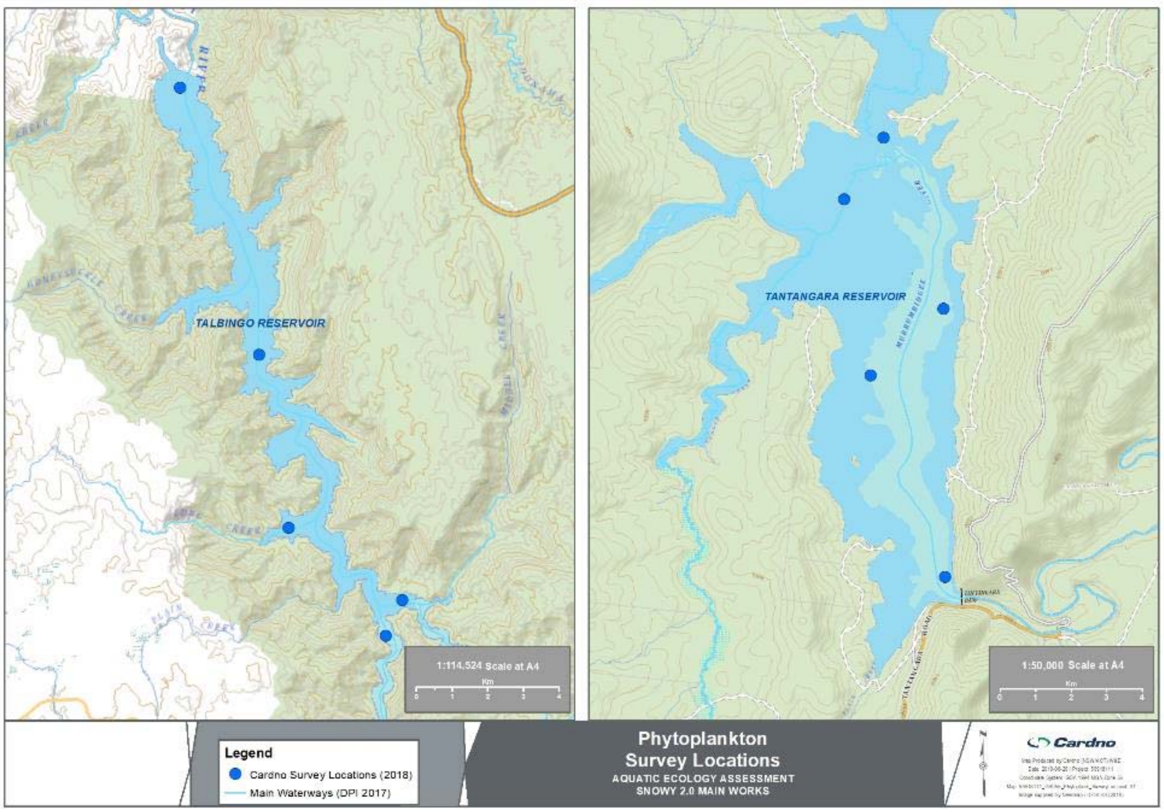


Figure 3-14 Phytoplankton sampling locations within Talbingo and Tantangara reservoirs.

3.4 Suitability of Methods

Backpack electrofishing, boat-based electrofishing, fyke nets, bait traps and gill nets are methods of sampling fish recognised by DSEWPC (2011). Backpack electrofishing and fyke nets used in watercourses are suitable for larger bodied fish in the family Percichthyidae (such as trout cod and Macquarie perch) and backpack electrofishing and bait traps are suitable for smaller bodied fish such as those in the family Galaxiidae (such as mountain galaxiid and climbing galaxiid). Bait traps and fyke nets were also set overnight (DSEWPC, 2011). Gill nets and boat-based electrofishing undertaken in the reservoirs are also suitable for capture of larger fish such as percichthyids and bait traps deployed here are suitable for capture of smaller gudgeons (Family: Eleotridae). These methods are also suitable for capture of non-native fish species including redfin perch, carp, goldfish and eastern gambusia.

The use of environmental DNA techniques is becoming increasingly accepted in Australia and overseas. Quantitative comparisons with traditional sampling methods indicate that eDNA methods can be superior in terms of sensitivity and cost efficiency, particularly for scarce, elusive or cryptic species (Biggs et al. 2015;

Lugg et al., 2018; Smart et al., 2015; Weeks et al., 2015), enabling detection of species at low densities. For example, a project specifically aimed at determining the efficacy of environmental DNA versus traditional fish capture methods (such as netting) in Lake Windermere, UK, detected 14 of 16 species known to occur there compared with four species detected using traditional methods (Hänfling et al., 2016). Further work is underway to demonstrate repeatability of the results through time and in different waterbodies. The findings of studies based on environmental DNA provide a tool in determining biodiversity values and the distribution of species. Given the technique is in relative infancy, the findings must be examined with caution and only with respect to other available data on species' distributions obtained using traditional methods, the ecology of different species and knowledge of the field and laboratory methods used by environmental DNA studies. As such, DNA detections with low (i.e. ≤ 1 %) relative abundance and / or with a low rate of detection (the number of sites in an area where it was detected was low compared with the number where it was not detected) that are not supported by previous catch records and / or field surveys undertaken during this assessment are treated with caution and not considered to represent the presence of live fish for the basis of this assessment. Rather, they are considered to represent a low likelihood of occurrence (**Section 6**).

3.5 Limitations

The survey data presented provided a snapshot of fish populations in the reservoirs and watercourses at the time of sampling and are, therefore, useful in providing general baseline information on presence / absence for the AEA but do not provide information on temporal variability of fish communities within the study area. Several factors such as time of day, varying depths and water quality (for example), as well as sampling effort may have influenced any spatial variability observed. Seasonal sampling would be required to allow for more definitive statements to be made on fish distribution within the reservoirs and watercourses. Notwithstanding, the project has used a range of sampling techniques to successfully and repeatedly verify the presence of a number of species of fish that were expected to occur within the study area.

4 Synthesis of Literature, Databases and Monitoring Data

4.1 Threatened Species and Populations

Based on the review of existing information and database searches the following threatened species and populations were assessed for their potential to occur within the study area.

4.1.1 Macquarie perch (*Macquaria australasica*)

The Macquarie perch is listed as endangered under the FM Act and EPBC Act. Macquarie perch is an elongated, oval shaped fish with a rounded tail and large eyes and mouth. It can grow to 55 cm and 3.5 kg in weight but generally occurs at less than 40 cm and 1 kg (DPI, 2016b). The colour of Macquarie perch within the Murray-Darling Basin varies from black to silver/bluish grey to green-brown dorsally and lighter ventrally, with juveniles sometimes mottled in colour (DPI, 2016b). It prefers clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks and is found in both river and lake habitats, especially in the upper reaches of rivers and their tributaries (DPI, 2016b). It spawns in spring or summer and lays eggs over stones and gravel in shallow, fast-flowing upland streams or flowing parts of rivers. Macquarie perch inhabiting impoundments would likely undertake upstream spawning migration in October to mid-January after which adults usually return to the impoundments. Migration may not be necessary in stream-dwelling fish. Macquarie perch is an active predator of macroinvertebrates. While other large-bodied perch-like fish are generally higher-order ambush predators that may have limited range, the Macquarie perch tends to have a relatively larger linear (along shore) diel range (Ebner et al., 2010). A study in a Canberra reservoir found that Macquarie perch has a mean linear diel range of 516 m (± 89 S.E.) which suggests that small and discontinuous pools would not provide preferred habitat for this species (Ebner, et al., 2010).

Its historic distribution included the Tumut River and Murrumbidgee River catchments (NSW DPI, 2017a). They are now found in the upstream reaches of the Lachlan, Murrumbidgee and Murray Rivers, and parts of south-eastern coastal NSW, including the Hawkesbury-Nepean and Shoalhaven Catchments (NSW DPI, 2017b). The National Recovery Plan for Macquarie Perch (DoEE, 2017) identifies self-sustaining populations in NSW in the upper Murrumbidgee River below Tantangara Reservoir upstream of Gigerline Gorge, Adjungbilly Creek, caught here most recently in February 2018 (Lintermans, 2019), in the Tumut River Catchment, the upper Lachlan River, Mannus Creek and other tributaries of the upper Murray River and the Hawkesbury-Nepean River system. Note that Macquarie perch in the Hawkesbury-Nepean system include stocked individuals as well as those occurring there naturally. A self-sustaining population also occurs in the ACT in the Cotter River and Cotter Reservoir upstream of Cotter Dam and below Bendorra Dam.

Macquarie perch was once widespread within the upstream reaches of the Murrumbidgee River Catchment; however, numbers have dramatically declined since the mid-1980s and it is now thought to exist as a series of scattered populations in the Murrumbidgee River upstream of the ACT, mostly in gorge country with intact vegetation cover (Lintermans, 2019). Anecdotal evidence suggests that it occurred as high up as Tantangara Reservoir, where it was relatively abundant after the dam filled in the late 1960s (its predicted distribution includes the Upper Murrumbidgee River upstream of Tantangara Reservoir dam wall). The population above Tantangara Reservoir dam wall is now thought to be extinct but a reliable angler report from 1991 suggests they occurred immediately below the dam wall as recently as this (Lintermans, 2019). It has been identified in the Murrumbidgee River upstream and downstream of Angle Crossing (ALS, 2011, Biosis, 2009), upstream of the ACT/NSW border in 2004 and 2017 (NSW DPI, 2017b) and near Williamsdale, Cooma and Adaminaby (Lintermans, 2019, and references therein). At present, it is thought that the uppermost population within the Murrumbidgee River extends from Cooma to just downstream of Yaouk Bridge (Lintermans 2019). Lintermans (2019) also includes a record at in the Murrumbidgee River at Tharwa Sandwash, just within the ACT. The presence of this population in the Murrumbidgee River upstream of the ACT/NSW border only was also supported by eDNA surveys undertaken upstream and downstream of this location for this study (**Section 5.2.6**). This population has demonstrated successful recruitment of the young-of-year (YOY) life stage most years (Lintermans, 2019). There is also a 2003 record from Numeralla River, a tributary of the Murrumbidgee River Catchment with a confluence between Bredbo and Cooma (Gilligan, 2005). The populations of Macquarie perch in the Murrumbidgee River upstream of the ACT, in Cotter Reservoir and Queanbeyan River (a tributary of the Murrumbidgee River with a confluence within the ACT) have a high level of genetic divergence, with important considerations with regard to the supplementation of declining populations with fish derived from other locations (Farrington, et al., 2014).

Talbingo Reservoir has reportedly been stocked with Macquarie perch in the past (Lintermans, 2007), including 10,000 fish in 1995 (Gilligan, 2005), and a stocked population was reported to occur in Talbingo

Reservoir (NSW DPI, 2017a). However, there are no records of it being stocked here in the last 10 years (NSW DPI, 2013b, 2017b) and it is uncertain if any individuals remain. There are 1999 and 2005 angler reports from Talbingo Reservoir and Blowering Reservoir, respectively (Lintermans, 2019). NSW DPI (2016a) indicates that the Tumut River and the lower Yarrangobilly River upstream of Talbingo Reservoir provide suitable habitat for this species though there are no known records for this species in these rivers (Dean Gilligan, NSW DPI (Fisheries), Pers. Comm. Sept 2017). Macquarie perch was not caught in Yarrangobilly River during the surveys by NSW DPI (over one day each in February 2007 and February 2016), in Talbingo Reservoir (over four days between 2004 and 2016), or during the boat-based electrofishing and gill nets surveys in Talbingo Reservoir and during the backpack electrofishing and fyke net surveys in Yarrangobilly River undertaken by Cardno (**Section 5.2**). No Macquarie perch DNA was detected in eDNA surveys in Talbingo Reservoir, Yarrangobilly River and Jounama Reservoir. These findings suggest that Macquarie perch is not present in Talbingo Reservoir and connected upstream watercourses.

Although Macquarie perch was translocated to the Snowy River around 1913 it has since not been recorded from there (Commonwealth of Australia, 2018), although several potentially unconfirmed records exist for the Lower Snowy River Catchment (ALA, 2019).

4.1.2 Trout cod (*Maccullochella macquariensis*)

Trout cod is listed as endangered under the FM Act and EPBC Act. It is a large-bodied predatory fish that was once widespread throughout the southern tributaries of the Murray-Darling Basin (NSW DPI, 2017c). It can grow to around 850 mm in length and up to 16 kg, although it generally occurs up to 500 mm in length and around 1.5 kg (NSW DPI, 2017c; McDowell, 1996). Its base colouration varies from olive to blue/grey with an overlay of small dark grey to black spots along its sides. The underside of the fish is paler in colour and can range from grey to white (NSW DPI, 2006a). It is similar in appearance to the closely related Murray cod (*Maccullochella peelii*), with distinguishing features including a dark horizontal eye stripe on the side of its head and an overhanging upper jaw (NSW DPI, 2017c; McDowell, 1996). Trout cod prefer areas with ample instream woody debris and snags are often found in close proximity to cover in relatively fast flowing currents (NSW DPI, 2017c; McDowell, 1996). It tends to be site-attached, and thus has a limited home range. Spawning occurs in spring and early summer, often when water temperatures are around 15°C, with females producing between 1,200 to 11,000 adhesive eggs that are attached to hard surfaces and then guarded by the male (NSW DPI, 2017c). Eggs generally hatch after five to 10 days, with larvae approximately 6 to 9 mm in length. Trout cod is a carnivorous top predator with a diet consisting of crustaceans, aquatic insects and fish (NSW DPI, 2017c; McDowell, 1996).

It was once widespread throughout the southern tributaries of the Murray-Darling River System, but has undergone a dramatic decline in distribution and abundance over the past century due to various pressures such as overfishing, altered flow and temperature regimes, habitat degradation, deterioration in water quality and competition from alien fish species (NSW DPI, 2017c; McDowell 1996). Its natural population is now limited to a single, self-sustaining population in the Murray River between Yarrawonga and Barmah (NSW DPI, 2017c). Its historic distribution included the Tumut River and Murrumbidgee River (NSW DPI, 2006a; DSE, 2008) and its predicted distribution includes the Murrumbidgee River upstream to Cooma and the Murray River upstream of Lake Hume but not the Swampy Plain River, Tumut River and Yarrangobilly River Catchments (NSW DPI, 2016a). It has been caught in the Murray River Catchment upstream of Lake Hume (ALA, 2019).

Lintermans (2019) includes a number of reports of trout cod from the Murrumbidgee River upstream of the ACT/NSW border including around Adaminaby and Cooma, and from just within the ACT border, from the 1970s to 2000s. A number of populations have been re-established within NSW from stocking programs of captive-bred fingerlings or through translocation as part of the 2006 NSW DPI Trout Cod Recovery Plan (Lintermans, 2019; NSW DPI, 2017c). The population in the Murrumbidgee River upstream of the ACT/NSW border now appears to be self-sustaining. Wild recruitment from irregular monitoring of these stocking efforts has been reported (Lintermans, 2019). Previously, trout cod were present in the Murrumbidgee River Catchment between Cooma and Tantangara Reservoir as recently as the 1960s/early 1970s but it became extinct within the area by the mid to late 1970s (Lintermans, 2019). As part of the National Recovery Program almost 335,000 individuals have been stocked in the upper Murrumbidgee River Catchment below Tantangara Reservoir between 1998 and to 2009 (Lintermans, 2019). In addition, there have been several stocking sites around and upstream of Cooma, with the most recent stockings occurring in 2008 (Lintermans, 2019). There are records of trout cod in the Murrumbidgee River downstream of Angle Crossing in the ACT (Biosis, 2009), near Cooma in 2007 (NSW DPI, 2017b) and a stocked and breeding population in the Murrumbidgee River at Narrandera (NSW DPI, 2006a).

Trout cod have recently been stocked in Talbingo Reservoir during 1996 (Lintermans, 2019), 2014, 2015, and 2016 (NSW DPI, 2019a) and there are angler reports from the late 1990s to 2009 (Lintermans, 2007).

Most recently, 6,000 trout cod fingerlings were stocked in Talbingo Reservoir in summer of 2018/2019 and there are reports of catches of trout cod here by anglers (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. May 2019). It was not caught during the NSW DPI surveys in Talbingo Reservoir and Yarrangobilly River, nor the most recent surveys undertaken for this study in 2018 and 2019 (**Section 5.2**). Although there is no evidence that trout cod are breeding or self-sustaining within these areas (Lintermans 2019), this possibility cannot be ruled out.

4.1.3 Murray cod (*Maccullochella peeli*)

Murray cod is listed as vulnerable under the EPBC Act. It is the largest freshwater fish in Australia, reaching 1.8 m in length and weighing 114 kg. It is coloured with a green mottled pattern on the dorsal surface and along the sides, with a cream to white belly. It is characterised by a large mouth, broad head and rounded tail. It is found in diverse habitats including flowing and standing waters, small, clear, rocky streams on the inland slopes and uplands of the Great Dividing Range; and in large, turbid, meandering slow-flowing rivers, creeks, anabranches, and lakes and larger billabongs of the inland plains of the Murray-Darling Basin (NMCRT 2010). Murray cod are usually found in association with large rocks, large snags and smaller structural woody habitat, undercut banks and over-hanging vegetation, but also frequent the main river channel and larger tributaries and anabranches. Murray cod form breeding pairs prior to spawning and a spawning site or nest is selected, usually a sunken log in lowland rivers, or a submerged rock in upland streams. Murray cod have also been recorded excavating and laying eggs in depressions in clay banks. Murray cod may migrate upstream to spawn, generally in late winter/early spring and this migration can be up to 120 km (Lintermans, 2007). Following spawning, fish move back downstream to the same area they occupied prior to migration, often to the same snag (Lintermans, 2007).

Murray cod were formerly widespread and abundant in the lower and mid-altitude reaches of the Murray-Darling Basin and its historic distribution included the Tumut River Catchment. It now has a patchy distribution and abundance across its historic range (MDBA, 2011a). Commercial fisheries data indicate that natural populations declined in the 1920s and then again dramatically in the 1950s. In the Tumut River Catchment, there have been large releases of hatchery-bred Murray cod within Blowering Reservoir and Jounama Pondage with a number of angler reports during 2000 to 2018 (Lintermans 2019). They are known to breed in Blowering Reservoir; however, they are sustained predominantly by stocking efforts (Lintermans 2019). Eleven Murray cod were caught in Jounama Pondage, just upstream of Blowering Reservoir, during the October 2018 Jounama Classic, an annual fishing event. They are also stocked in the Murray River upstream of Lake Hume and in Khancoban Pondage as recently as 2018/2019 (NSW DPI, 2019a).

Murray cod occur in the Murrumbidgee River in the ACT (Lintermans 2019; NMCRT 2010; Biosis, 2009); they were caught upstream of the ACT/NSW border in 2017 (NSW DPI, 2017b). They have been stocked downstream of Cooma, including approximately 4,000 Murray cod stocked between 2008 and 2011, and records from 1994 to 2006 (Lintermans 2019). The population in the Murrumbidgee River upstream of the ACT/NSW border is now considered to be self-sustaining. They are also reported to occur in Numeralla River (a tributary of the Murrumbidgee River), though the population in this river is not thought to be self-sustaining (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. May 2019). Murray cod are thought to be rarer in the Murrumbidgee River Catchment at or above Cooma (Lintermans 2019). Other than DNA detected in low relative abundance in Jounama Pondage, this species was not recorded in any surveys for this project (**Section 5.2.6**).

4.1.4 River blackfish (*Gadopsis marmoratus*) – Snowy River Catchment Population

Morphological and genetic data indicate that there are several distinct geographical forms of river blackfish. However, these are yet to be formally described as unique species (NSW DPI, 2014). River blackfish were once abundant in the Snowy River Catchment but are now found only along about 50 km of waterways of the Delegate River and some of its tributaries (NSW DPI, 2014). The Delegate River is a tributary of the Snowy River located outside of the Snowy Water Catchment below Jindabyne Dam. This East Gippsland form of river blackfish prefers clear flowing streams with good instream cover such as woody debris, aquatic vegetation and undercut banks. The northern river form, the northern river blackfish (**Section 4.3.3**), is located in the Murray-Darling Basin, though it is not listed as threatened. The predicted distribution in the Snowy River Catchment includes the Delegate River and its tributaries, the Eucumbene River between Eucumbene dam wall and Lake Jindabyne, and the lower Thredbo River and lower Mowamba River (DPI, 2016a). Below Guthega, the Island Bend and Jindabyne dams and the Eucumbene River below Eucumbene Dam are regulated by the Snowy Scheme and as a result these sections of river are unlikely to provide suitable habitat for this species. It was caught in the Snowy River Catchment by Gilligan & Williams (2008), presumably in the Delegate River. This species was not recorded with the Lake Eucumbene Catchment in any surveys undertaken in this catchment for this Project (**Section 5.2.6**).

4.1.5 Southern pygmy perch (*Nannoperca australis*)

Southern pygmy perch, listed as endangered under the FM Act, is generally considered a still water or wetland species (Kuiter et al*.,* 1996; Allen et al., 2002), though it probably once inhabited a range of habitats in the absence of disturbance. The historic distribution of southern pygmy perch included the Tumut River and Murrumbidgee River Catchments (NSW DPI, 2013c). Known populations are in the Lachlan River, including Blakney Creek (NSW DPI, 2015), in the Murray River Catchment in two small creeks (Coppabella Creek and Jingellic Creeks) near Jingellic (approximately 100 km downstream of Khancoban Reservoir) (NSW DPI, 2017d) and in the Snowy River downstream of Snowy Falls (from approximately 15 km to 20 km downstream of the confluence with the Delegate River) (Gilligan & Williams, 2008). They are also known to occur in wetland habitat near Khancoban below Khancoban Dam Wall (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. 2019). Its predicted distribution includes these areas, the Murray River and Swampy Plain River (including Khancoban Dam). Its predicted distribution also includes the Numeralla River (NSW DPI, 2016a), though it was not caught there during limited surveys undertaken by NSW DPI and there are no known records of its occurrence there (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. 2019). Southern pygmy perch are assumed to be absent from the Murray River Catchment upstream of Khancoban Pondage and from the Snowy River Catchment upstream of Jindabyne Dam. There is a historic (1976) record from the Tumut River downstream of Blowering Dam Wall (ALA, 2019). This species was not recorded in any surveys for this project (**Section 5.2.6**).

Southern pygmy perch has recently been nominated for listing as threatened under the EPBC Act. The consultation period for southern pygmy perch will end on 2 August 2019 upon which the Threatened Species Scientific Committee would make a determination. In the event this species is listed under the EPBC Act, a consistency assessment in accordance with the *Matters of National Significance: Significant Impact Guidelines 1.1* would be required with consideration to any newly approved conservation/recovery plans.

4.1.6 Silver perch (*Bidyanus bidyanus*)

Silver perch is listed as vulnerable under the FM Act. It was once widespread throughout much of the Murray-Darling Basin, including the Tumut River Catchment (NSW DPI, 2006b), but excluding the uppermost reaches of the basin (MDBA, 2011b). One large, self-sustaining population remains in the central Murray River downstream of Yarrawonga Weir (NSW DPI, 2017b). It was stocked in Blowering Dam (but not Jounama Pondage) downstream of Talbingo Reservoir dam wall in 2009 and in Googong Reservoir near the ACT/NSW border in 2016 (NSW DPI, 2019a). It has also been recorded from the Murrumbidgee River downstream of Angle Crossing (Biosis, 2009).

4.1.7 Stocky galaxias (*Galaxias tantangara*)

Stocky galaxias is listed as critically endangered under the FM Act. It is a small-bodied fish with a maximum length of approximately 100 mm, although is more commonly found from 75 to 85 mm in length (NSW DPI, 2018a). Its colouration on its back and upper sides is predominantly dark olive/brown, which becomes lighter to cream below the lateral line. Numerous dark brown/black blotches of varying sizes occur along its body and head (NSW DPI, 2018a). Its fins and gill covers are often translucent. Stocky galaxias is a relatively newly described species that is part of the mountain galaxias (*Galaxias olidus*) complex. Very little is known about its ecology, with limited information on its environmental requirements. Its current habitat is a small, cold, fast-flowing alpine creek with clear water that flows through an open forest of eucalypts, low shrubs and tussock grasses (NSW DPI, 2018a). The creek above the waterfall generally consists of riffle and glide habitat. The substratum is predominantly made up of bedrock, boulders and cobble with small sections of pebble, gravel and silt (NSW DPI, 2018a). Its reproductive ecology is unknown but is assumed to be similar to closely related galaxiid species (i.e. Mountain galaxias), with low fecundity (less than 400 eggs annually) and spawning thought to occur during winter (NSW DPI, 2018a). Eggs are adhesive and attached to the underside of rocks within riffle habitat and hatch after 20-30 days. Its movement patterns are considered to be similar to that of mountain galaxias with its home range likely to be limited to less than 100 m (NSW DPI, 2018a). Its diet is thought to comprise aquatic insect larvae and terrestrial insects that fall into the water from stream edges (NSW DPI, 2018a).

It has an extremely limited distribution within a small section (approximately 3 km) of Tantangara Creek above a waterfall (i.e. Upper Tantangara Creek) which is thought to exclude predatory trout present downstream (Lintermans, 2019). The species is thought to have lost more than 90% of its former range within the Tantangara Creek Sub-catchment, with wider sampling within the area not identifying any individuals of this species (Lintermans, 2019).

4.1.8 Eel tailed catfish (*Tandanus tandanus*) (Murray-Darling Basin Population).

There is one pre-1980s record in the Murrumbidgee River Catchment near Cooma (MDBC 2007a) and a 1990s record from within the ACT (ALA, 2019). Its predicted distribution includes Burrinjuck Dam and sections of the Murrumbidgee River just upstream of here and in the ACT, but not upstream of the ACT/NSW border (NSW DPI, 2016a). This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.1.9 Murray crayfish (*Euastacus armatus*)

Murray crayfish is listed as vulnerable under the FM Act. It is the second largest freshwater crayfish in the world (NSW DPI, 2019b). It has a dark green to green-brown body and three rows of large white spines on each side of its tail. In addition, it possesses two large bright white claws (chelae) which lighten in colour with age (NSW DPI, 2019b). Individuals can exceed 150 mm carapace length and 2.5 kg in weight. As with other crustaceans, Murray crayfish grow sequentially through a series of moults, with juveniles moulting up to ten times in their first year (NSW DPI, 2019b). Murray crayfish prefers cool, well oxygenated flowing water and is found in a range of environments, such as pasture-lands to sclerophyll forest. It tends to be most active in the cooler months between May and October and becomes less active during the warmer months (NSW DPI, 2019b). It is a long-lived, slow growing species, with females and males taking up to 10 and four years to reach sexual maturity, respectively, and can live up to 28 years of age. It is thought that mating is cued by the rapid drop of water temperatures observed in May. Large females have the potential to produce up to 2,400 eggs, with eggs incubated under their abdomen for a period of around 20 weeks (NSW DPI, 2019b). Following this, the hatchlings remain in the female's care for around another month before dispersing. It is an opportunistic feeder with a wide dietary range and is able to feed on decaying aquatic plant matter, dead fish and other animals. Cannibalism has also been reported within high-density populations (NSW DPI, 2019b).

Murray crayfish is endemic to the Murray-Darling Basin, including the Murrumbidgee River and many of its tributaries (NSW DPI, 2019b). The Murray crayfish population has suffered a significant decline over the last 50 years, with severe flooding, river regulation and various land practices causing high mortality and slow recovery (Lintermans, 2019; NSW DPI, 2019b). It is present currently in the riverine habitats and impoundments (e.g. Burrinjuck Dam) in the Murrumbidgee River Catchment upstream and downstream of Angle Crossing (Lintermans, 2019; Biosis, 2009), including the Tumut River Catchment, and in the Murray River.

NSW DPI supplied data from sampling of Murray crayfish undertaken at a number of sites within Honeysuckle Bay in August 2013. In total, 19 crayfish were captured between 5 m and 8 m water depths during this survey (NSW DPI, unpublished data). Surveys undertaken in Talbingo and Blowering Reservoirs during the winter months of 2008, 2009 and 2010 by Zukowski et al*.,* (2013) caught a total of 188 Murray crayfish in Talbingo Reservoir (to a depth of 28 m) and 19 in Blowering Reservoir over the three years of sampling. Results indicated that abundance of Murray crayfish did not vary significantly between years for both reservoirs. More recently, Zukowski & Whiterod (2019) undertook targeted crayfish sampling within Talbingo Reservoir during June 2019 using different gear types and caught a total of 19 Murray crayfish from 880 net retrievals from 11 of the 14 sites throughout the reservoir (all but one specimen were found in depths less than 10 m). Results suggested that there was a marked reduction in relative abundance of crayfish across the broader reservoir when comparing previously sampled sites over time and it was thought that the decline could be as a result of the invasion of Canadian pondweed (*Elodea Canadensis –'Elodea'*), that has established throughout of the reservoir.

NSW DPI caught Murray Crayfish from Jounama Creek, downstream of Talbingo Reservoir in 2016, and in Swampy Plains River in the Murray River Catchment in 2011 (NSW DPI, 2017b) and reports exist from Blowering Reservoir, Jounama Pondage and Talbingo Reservoir and the Murrumbidgee River upstream of the ACT (Lintermans, 2007) It was caught in the Yarrangobilly catchment (including Wallaces Creek and Yarrangobilly River) in the current study (**Section 5.2**) and DNA from Murray crayfish was detected in Yarrangobilly River and Wallaces Creek and in low relative abundance in in Talbingo Reservoir (**Section 5.2.6**). It has been observed in T2 Reservoir (Snowy Hydro Pers. Comm. 2018). It is not known to occur in the Tantangara Reservoir Catchment (Lintermans, 2019). Murray crayfish are much more abundant in the upper Tumut River system, particularly in the Talbingo and Blowering Reservoirs, compared with the upper Murrumbidgee River Catchment (Lintermans, 2019). There are records from Khancoban Pondage from the 1980s (NSW DPI, 2007).

4.1.10 Alpine redspot dragonfly (*Austropetalia tonyana*):

Alpine redspot dragonfly has a very restricted distribution to the splash zone of waterfalls within alpine areas of the Snowy River Catchment. There are records from the Geehi River downstream of Geehi dam wall and from the upper Snowy River Catchment (outside of the study area) (ALA, 2019). Its predicted distribution includes watercourses west of Lake Jindabyne and Lake Eucumbene, including the upper Eucumbene River, upper Tumut River Thredbo River, Gungarlin River, Geehi River, and the upper Swampy Plain River (FSC, 2014). Threats to alpine redspot dragonfly include habitat disturbance and modification due to reductions in rainfall and stream flow associated with climate change (FSC, 2014). Bushfires (and associated inputs of sediment) and reductions in stream flow associated with forestry development are also potential threats.

4.2 Not Present

Threatened species of the Murray-Darling River Basin and Snowy River Catchment not considered present within the study area include:

> Flathead galaxias (*Galaxias rostratus*): Considered locally extinct in the lower Murrumbidgee River with only very small populations recorded in the upper Murray River near Tintaldra and Albury more than 40 km south-west from the study area. Predicted distribution does not include study area (NSW DPI 2016a) and not present in the Snowy River Catchment (Pers. Comm. (2019) Raadik, T. Arthur Riley Institute Victoria);

> Australian grayling (*Prototroctes maraena*): Coastal species not in Study area (occurs in Lower Snowy River (Gilligan & Williams, 2008). Historic reports of this species occurring in the Snowy River as far upstream as the current Lake Jindabyne (Bell et al*.,* 1980; Lake, 1971). However, substantial natural barriers now exist between there and the coast and it is considered extinct in the lake. It's predicted distribution does not include the study area (NSW DPI 2016a);

> Hanley's river snail (*Notopala hanleyi*): This species is only known to occur in one location in NSW and two in South Australia. The location in NSW (Dareton) is over 500 km west of the study area;

> Murray hardyhead (*Craterocephalus fluviatilis*): This species is known only from one location in NSW and two in South Australia. The location in NSW (Dareton) is over 500 km west of the study area. No viable populations are known in NSW and it is considered locally extinct in the Murrumbidgee River Catchment. No collection records from the study area (MDBC, 2007b);

> Southern purple spotted gudgeon (*Mogurnda adspersa*): This gudgeon occurs in coastal streams of northern NSW and Queensland, as well as the Murray-Darling Basin (MDBA, 2009). No recent records from the Murrumbidgee River Catchment and the predicted distribution does not include the study area;

> Olive perchlet (*Ambassis agassizii*): formerly present in lower Murrumbidgee, Lachlan and lower Murray Rivers. In NSW it is known only from a few localities in the Darling River upstream of Bourke (MDBA, 2009) and the predicted distribution does not include the study area;

> Barred galaxias (*Galaxias fuscus*): The barred galaxias is only found in the headwaters (above 400 m altitude) of the Goulburn River catchment in the central highlands of Victoria, in the southern Murray-Darling Basin (MDBA, 2009); and

> Yarra pygmy perch (*Nannoperca obscura*): Occurs in the Murray-Darling Basin in Lake Alexandrina in the lower Murray River, outside of the study area (MDBA, 2009).

4.3 Native Fish

Based on the review of existing information and database searches the following native fish species were identified to occur or have potential to occur within the study area.

4.3.1 Golden perch (*Macquaria ambigua ambigua*)

Golden perch is found predominantly in lowland, warmer, turbid, slow flowing rivers often associated with snags and other cover (MDBA, 2007a). Adult and immature fish are migratory and extensive upstream movements of more than 1,000 km have been recorded for some adult fish, although movements of this scale are not common. Outside the breeding season, individuals occupy home ranges of about 100 m for weeks or months before relocating to another site where a new home range is established. Upstream movements by both immature and adult fish are stimulated by small rises in streamflow, and most movement in the Murray River occurs between October and April. Golden perch were stocked in Jounama Pondage and Blowering Reservoir throughout 2009 to 2017, and in Googong Dam (on the Queanbeyan River, a tributary of the Murrumbidgee River with a confluence within the ACT) during 2010 to 2017 (NSW DPI, 2019a). They have been reported to occur in Numeralla River in the Murrumbidgee River Catchment upstream of the ACT and downstream of Angle Crossing (Biosis, 2009). There are records of golden perch in Blowering Reservoir and the Murrumbidgee River in the ACT (Lintermans, 2019). Other DNA detected in low relative abundance at one site in Talbingo Reservoir and three sites in Jounama Pondage, this species was not recorded in any surveys for this project (**Section 5.2.6**)

4.3.2 Two-spined blackfish (*Gadopsis bispinosus*)

The two-spined blackfish is a small to medium-sized species that can grow to 300 mm in length, but it is rarely found greater than 250 mm (McDowell, 1996). Its colouration is variable but generally consists of a pale yellowish basal colouration overlayed by a series of two or three rows of dark brown blotches, often quite mottled along its length. The outer margins of its caudal, dorsal and anal fins are colourless, bordered by a thin, dark stripe (McDowell, 1996). It tends to inhabit more upstream reaches of the Murray River and Murrumbidgee River Catchments than river blackfish, which tends to be found in the mid to lower reaches of these catchments. It shows a distinct preference for clear, cool, medium to larger upland streams that are comprised of coarse gravel/boulder substratum with woody debris that can provide cover from stronger water flows (Lintermans, 2019; McDowell, 1996). It is usually found in forested catchments with little sediment input and has a very limited home range, typically less than 15m (Lintermans, 2007). It spawns in spring and early summer, with larger females often spawning earlier in the season than smaller females. Spawning habitat is thought to be in gaps between cobbles or boulders, where between 80 and 240 adhesive eggs (within a mass) are attached to the upper surface of rocks. Eggs are fanned and guarded by the males during the spawning season (Lintermans, 2007). Diet generally consists of aquatic insect larvae, particularly mayflies, caddisflies and midges, although it can prey on small fish and crayfish (Lintermans, 2007). Significant threats include cold-water pollution, river regulation, smothering of eggs and spawning sites by sediment, and interactions with trout, particularly predation by trout and competition for food (MDBA, 2007b). Interactions with these and other non-native fish, including redfin perch, are thought to be the primary threat to two-spined blackfish, contributing to its listing as a Vulnerable species in the ACT (ACT, 2018)

The two-spined blackfish is found only in the Murray-Darling Basin (MDBA, 2007b). Its general distribution includes north-eastern Victoria through to south-eastern NSW and the ACT. In NSW it is often abundant on the eastern side of the upper Tumut River Catchment, occurring in a number of tributaries of the Goobarragandra River (a tributary of the Tumut River below Blowering dam wall); the Tumut River (Lintermans, 2019); Talbingo Reservoir, Jounama Creek, Yarrangobilly River and Swampy Plain River (NSW DPI, 2017); and the Murray River below Khancoban Pondage and Geehi River below Geehi Reservoir (ALA, 2019). A small remnant population is still present in the Murrumbidgee River above Cooma (MDBA, 2007b) and there are also records from the Murrumbidgee River near Adaminaby (Lintermans, 2019). DNA from two spinned blackfish was detected Talbingo Reservoir and Yarrangobilly River, and in low relative abundance in Jounama Reservoir (**Section 5.2.6**).

4.3.3 Northern river blackfish (*Gadopsis marmoratus*) – Murray-Darling Basin Population

Outside of the Snowy River Catchment, the northern river blackfish is known from the Murray River and the mid to upper reaches of the Murrumbidgee, Macquarie, Lachlan, Gwydir and Namoi Rivers in NSW. It also occurs in southern Queensland, and in Victoria and Tasmania. It has been reported from below Khancoban Pondage and the Tumut River Catchment below Blowering Reservoir (ALA, 2019). This northern form is more secretive and bottom-dwelling, inhabiting a range of habitats including small upland and lowland creeks, fast flowing rivers and turbid streams, compared with that in the Snowy River Catchment (the East Gippsland form) (NSW DPI, 2014) (**Section 4.1.4**). It has also been caught in Gilmore Creek and Adjungbilly Creek in the Lower Tumut River Catchment (Lintermans, 2019). This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.3.4 Climbing galaxias (*Galaxias brevipinnis*)

Climbing galaxias is a relatively large, native galaxiid that can grow to 278 mm in length, although it is more commonly found at sizes of 150 mm to 180 mm. Its body colouration is greyish brown to olive, often with distinct dark stripes/blotches on the dorsal and lateral surface, with the underside often a dull silvery/olive colour (MDBC, 2007c). It is native to coastal streams and drainages in south-eastern Australia where larvae are thought to be swept downstream to the sea, where they remain for 5 to 6 months before migrating back into estuarine and freshwater habitats. However, it has been transferred to inland catchments in the Murray-Darling Basin (such as the Geehi River catchment) reportedly via the Snowy Hydro Scheme, where these landlocked populations can survive and reproduce by using large freshwater impoundments to fulfil the role of the marine environment for larval development. Adult fish prefer clear, fast-flowing shady streams with rocks, boulders and logs, usually well upstream in headwaters. In coastal streams, climbing galaxias usually breeds during autumn and winter, where it scatters its adhesive eggs amongst vegetation along the damp stream edge above the normal flow level during flood conditions. The reproductive ecology of landlocked populations in the Murray-Darling Basin is unknown, though it is thought that spawning generally occurs in late April or early May (MDBC, 2007c). As its name implies, climbing galaxiid is able to traverse vertical waterfalls, damp rock faces and other fish barriers, sometimes tens of metres high. Its diet consists mainly of aquatic invertebrates such as mayflies, caddisflies, dipterans and small crustaceans (MDBC, 2007c).

Its distribution is generally restricted to coastal streams in south-eastern Australia and New Zealand, including the Snowy River Catchment; however, it can sustain landlocked populations. It was first recorded from the Tumut River Catchment in 2002 from Morris Creek, a small tributary of Blowering Reservoir (Lintermans, 2019). Since this initial capture, none were found there until it was recently sampled in the Yarrangobilly River in the current study (**Section 5.2.6**). There are no records of climbing galaxias in the Murrumbidgee River system, other than those from Morris Creek and the Yarrangobilly catchment. It is considered absent from the Murrumbidgee River Catchment upstream of Burrinjuck Dam (Lintermans, 2019). It was caught in the Geehi River upstream of Geehi Dam in the upper Murray catchment in 2005, 2008 and 2011 (NSW DPI, 2017b) and there are records from here and Tooma River just downstream of Tooma Reservoir (from 1992) and an historic (1973) record from Lake Eucumbene (ALA, 2019). DNA from climbing galaxias was detected in Yarrangobilly River, Lake Eucumbene, Lake Jindabyne and Swampy Plain River Catchments (**Section 5.2.6**). It was not detected in targeted eDNA surveys in the T2 Reservoir and Mid and Lower Murrumbidgee River Catchments.

4.3.5 Mountain galaxias (*Galaxias olidus*)

Mountain galaxias occurs in a variety of habitats from small creeks to large rivers and is widely distributed throughout south-eastern Australia (MDBA, 2009), including the Murrumbidgee River at Angle Crossing (Biosis, 2009), although they are the only native fish that is found in the alpine zone above the snowline during winter. Populations are not restricted to the mountains, also being found in lowland habitats. Other galaxiid species are more abundant and widespread in lowland rivers. They are also present in the Snowy River Catchment downstream of Jindabyne dam wall (Gilligan & Williams, 2008). Where trout are abundant they may be restricted to very shallow edge habitats or riffles. Mountain galaxias is relatively variable and has recently undergone a taxonomic redescription and at least 15 separate species are now recognised (Raadik, 2014). They have been caught in the Murrumbidgee River Catchment downstream of Tantangara Reservoir dam wall (Lintermans, 2019; NSW DPI, 2017b) and in the upper Murray River Catchment in Tooma River and Swampy Plains River (NSW DPI, 2017b) and considered present in Yarrangobilly River (Pers. Comm. (2019) Raadik, T. Arthur Riley Institute Victoria). Records exist from the Geehi River downstream of Geehi Dam and the Tumut River Catchment upstream of T2 Dam (ALA, 2019), and in the Blowering River catchment (Lintermans, 2019; Raadik, 2014). DNA from the species complex was detected in Talbingo Reservoir, Tantangara Reservoir and Upper and Mid-Murrumbidgee catchments. Individuals from the species complex, tentatively identified as *G. olidus* (Raadik, 2018), were caught during electro-fishing in the Upper and Mid Murrumbidgee catchments (**Section 5.2.6**).

4.3.6 Common galaxias (*Galaxias maculatus*)

Common galaxias ('jollytail') is a coastal species not found in the Murrumbidgee River or in the Snowy River upstream of Jindabyne Dam. It has been introduced recently into Dartmouth Dam, on the Mitta Mitta River in Victoria, by anglers. It may spread to the Murray River, though spread upstream may be limited by low water temperatures (Pers. Comm. (2019) Raadik, T. Arthur Riley Institute Victoria). This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.3.7 Riffle galaxias (*Galaxias arcanus*)

Riffle galaxias is known from the Murray River system in Victoria and NSW, extending to the headwaters of the Murray River and to mid reaches of tributaries of the Murray River in NSW upstream of Lake Hume (ALA, 2019). It has not been recorded from the Murrumbidgee River system (Pers. Comm. (2019) Raadik, T. Arthur Riley Institute Victoria). This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.3.8 Roundsnout galaxias (*Galaxias terenasus*)

Roundsnout galaxias occurs in the south-eastern corner of southern NSW and East Gippsland, Victoria, and in the mid Snowy, Cann and Genoa River systems (ALA, 2019). In the Snowy River, it has been recorded from Burnt Hut Crossing (approximately 500 m above sea level), Maclaughlin River system (to 780 m above sea level) and is widespread in the Delegate/Bombala River systems (760 and 785 m above sea level respectively (Raadik, 2014). It is not found in Murrumbidgee River system, and is restricted to mid reaches of the Snowy River (and tributaries), downstream from Dalgety. This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.3.9 Australian smelt (*Retropinna semoni*)

Australian smelt is one of the most widespread and abundant species at lower and mid altitudes in south-eastern Australia (MDBA, 2007c). It is not generally found in upland headwater streams with fast flows in the southern Murray-Darling Basin. It has been recorded in the Murrumbidgee River up and downstream of Angle Crossing (Lintermans, 2019; Biosis, 2009) and in the Murray River and Tumut River Catchments

(Lintermans, 2019; MDBA, 2007c). It also occurs in the Snowy River Catchment upstream and downstream of Snowy Falls (Gilligan & Williams, 2008) and in the Swampy Plain River and Lower Tumut River Catchments (ALA, 2019). DNA Australian smelt was detected in Talbingo Reservoir, though in low relative abundance (**Section 5.2.6**).

4.3.10 Flat-headed gudgeon (*Philypnodon grandiceps*) and Dwarf flat-headed gudgeon (*Philypnodon macrostomus*)

Flat-headed gudgeon was thought to be relatively widespread throughout the Murray-Darling basin but recent surveys suggest its distribution is patchy (MDBA, 2009). It occurs in the Murrumbidgee River upstream of the ACT and in coastal streams in Victoria, NSW and South Australia, though its distribution may be patch (MDBA, 2009) including the Snowy River Catchment (Gilligan & Williams, 2008). Records exist from Blowering Reservoir, the Lower Tumut River Catchment and the Murray River Catchment upstream of Lake Hume (ALA, 2019). DNA from Flathead gudgeon was detected in Talbingo Reservoir and the Eucumbene River catchment and in low relative abundance in Jounama Pondage (**Section 5.2.6**).

Dwarf flat-headed gudgeon occur in the Murray-Darling basin and in coastal streams. Their distribution in the Murray-Darling Basin is also patchy and it is known from the Murrumbidgee River near Canberra and the upper Murray near Albury (Lintermans, 2007).

4.3.11 Carp gudgeon (*Hypseleotris* spp.)

There is some confusion surrounding the identification of carp gudgeon in south-eastern Australia and at least four taxa are present (MDBA, 2009). They are found in slow-flowing or still waters, normally associated with aquatic vegetation. In the Murrumbidgee River they occur as far upstream as the ACT (MDBA, 2009) and were identified downstream of Angle Crossing (Biosis, 2009) and in the Lower Tumut catchment and Murray River Catchment upstream of Lake Hume (ALA, 2019). This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.3.12 Short-finned eels (*Anguilla australis*) and longfinned eels (*Anguilla reinhardtii*)

Shortfinned and longfinned eels are generally only recorded from coastal streams outside the Murray-Darling Basin. Most inland records of shortfinned eel are assumed to be of fish translocated from coastal streams by anglers, but some represent natural dispersal events. There are occasional records in the Basin from the upper Murrumbidgee River (possibly translocated via the Snowy Scheme) (MDBA, 2009). The only known records of longfinned eel from the Murray-Darling Basin are in the Condamine-Balonne drainage in southern Queensland and the Lower Lakes of the Murray in South Australia. Both species have been caught upstream and downstream of Snowy Falls in the Snowy River (Gilligan & Williams, 2008) and the longfinned eel has been caught in the Eucumbene River near the junction of The Link Road and Snowy Mountains Highway in 1998 (NSW DPI, 2017b). Both these species migrate to sea to spawn, hence are most unlikely to form self-sustaining populations in the study area. DNA from short-finned eel was detected in low relative abundance in in Talbingo Reservoir and Tantangara Reservoir (**Section 5.2.6**).

4.3.13 Yabbies (Cherax spp.)

There are several species of yabbies the most common of which is the common yabby (*Cherax destructor*), which has a high tolerance to a variety of aquatic environments. They are not native to the upper Murrumbidgee River but are often translocated by anglers and for aquaculture. Coastal and inland species exist. *Cherax* sp. was caught in Grosses Plain Creek in the Snowy River Catchment and in the Murrumbidgee River downstream of Tantangara Reservoir dam wall, Tumut Pond Reservoir and Lower Snowy River Catchment (NSW DPI, 2017b). There are records from the Lake Eucumbene, Lake Jindabyne, Swampy Plain River, Murray River and the Lower Murrumbidgee River Catchments (ALA, 2019). DNA from common yabby was detected in Talbingo Reservoir and Tantangara Reservoir, and the catchments of the Blowering Reservoir, Upper and Mid Murrumbidgee River and Lake Eucumbene (**Section 5.2.6**). It was also caught in Talbingo Reservoir and Tantangara Reservoir as part of this assessment (**Section 5.2**).

4.3.14 Reik's crayfish (Euastacus reiki)

Reik's crayfish is found above 1,000 m elevation. They are major processors of organic matter and an important source of food for other invertebrates, frogs, fish and platypus. They also assist in maintaining river health and structure. Habitat loss and modification are listed as the major threats to this species. They are highly dependent on constant, clear, good quality water flows, with reliable dissolved oxygen levels. It has been caught in Nungar Creek and in Betts Creek in the Snowy River near Guthega Pondage in the Lake Jindabyne Catchment (NSW DPI, 2017b) and has been recorded from the Mid Murrumbidgee River (ALA, 2019). DNA from Riek's crayfish was detected in Tantangara Reservoir and catchments of the Upper

Murrumbidgee River and Lake Eucumbene (**Section 5.2.6**). It was also caught in several watercourses in the Upper Murrumbidgee River Catchment and in Eucumbene River as part of this assessment (**Section 5.2**).

4.3.15 Alpine spiny crayfish (*Euastacus crassus*)

Alpine spiny crayfish is found above 600 m. This species of crayfish is very similar in external morphology to Reik's crayfish and usually require removal of the digestive grinding apparatus (gastric mill) for positive identification. There are historic records from the mid and lower Murrumbidgee River downstream of Tantangara Reservoir dam wall and from the Lake Jindabyne catchment (ALA, 2019). Recent records exist from the Lower Tumut River Catchment, Lower Snowy River Catchment and Swampy Plain River Catchment. DNA material corresponding to the genus *Euastacus* was detected in Wallace's Creek in the Yarrangobilly River Catchment but the identity of the species could not be confirmed due to lack of genetic reference material (**Section 5.2.6**).

4.3.16 Burrowing crayfish (*Engaeus cymus*)

Historic records indicate that the burrowing crayfish was recorded in the Yarrangobilly River and in the Lower Murrumbidgee River Catchment, and more recent records from Blowering Catchment, Lower Tumut dam wall and Swampy Plain River Catchment (ALA, 2019). This species was not recorded in any surveys for this project (**Section 5.2.6**).

4.3.17 Other Native Species in the Lower Snowy Catchment

The following species are known to occur below Jindabyne dam wall, however, they have not been reviewed in detail as there are no known recent records upstream of snowy falls:

> Striped gudgeon (*Gobiomorphus australis*);
> Pouched lamprey (*Geotria australis*);
> Congoli (*Pseudaphritis urvillii*);
> Australian bass (*Macquaria novemaculeata*);
> Cox's gudgeon (*Gobiomorphus coxii*); and
> Spotted galaxias (*Galaxias truttaceus*).

4.4 Non-native Species

Based on the review of existing information and database searches the following non-native fish species were identified to occur within the study area.

4.4.1 Redfin perch (*Perca fluviatilis*)

Redfin perch is a medium-sized freshwater fish native to northern Europe. It was introduced to Australia in the 1860s for angling purposes and is now widespread across much of NSW, ACT, Victoria, Tasmania, south-eastern South Australia and the south-western corner of Western Australia. Although a popular sport fish, it is a notifiable species under the NSW Biosecurity Regulation 2017. It is a voracious predator that can outcompete other fish species and decimate recreational fisheries and native fish populations (NSW DPI, 2018b). In addition, it can carry the Epizootic Haematopoietic Necrosis Virus (EHNV), which has been shown under laboratory conditions to infect several native fish species of the Murray-Darling Basin (such as Macquarie perch, silver perch, trout and mountain galaxiid) and destroy blood-forming organs such as the kidneys and spleen (NSW DPI, 2018b). Redfin perch are characterised by a deep body and a slightly forked tail, with two distinct, separate dorsal fins. Its colouration includes a number of dark vertical bands across the dorsal surface with the body colour varying from olive green to grey on the back, sometimes fading to greenish or silvery sides and a whitish belly. Its pelvic, anal and caudal fins are often a bright reddish/orange colour. It can grow up to 60 cm in length and weigh 10 kg, although it occurs typically at up to 45 cm and 1-2 kg.

Redfin perch prefer still or slow-flowing waters such as dams, lakes, swamps and slower moving streams and rivers with shelter such as submerged dead wood and trees, vegetation or rocks. It spawns in late winter and spring by laying several hundred thousand eggs in a gelatinous ribbon within sheltered areas such as aquatic vegetation and submerged logs/rocks (NSW DPI, 2018b). This egg ribbon is unpalatable, so is generally not preyed upon by most other fish species. The eggs are quick to develop and usually hatch in around a week. Individuals are generally mature after approximately two years; however, males are known to mature at the end of the first year (MDBA, 2009). It preys on a wide variety of food items including small invertebrates and fish. Redfin perch are reported to have relatively poor swimming ability, with mean maximum sustained swimming speeds of 0.15 m/s (SD: 0.00) and burst swimming speeds of 0.32 m/s (SD: 0.02), slower than two species of galaxiid (*Galaxias maculatus* and *Galaxias truttaceus*), Congolli (*Pseudaphritis urvillii*), and non-native Brown trout (*Salmo trutta*) (Davies, 2000 in Knight, 2010). These estimates were consistent for redfin perch across of fork lengths of 82 mm to 221 mm.

Redfin perch are present throughout the Murrumbidgee River Catchment, including the Tumut River Catchment, Blowering Reservoir and Talbingo Reservoir. They have also been caught in associated tributaries, including the Tumut River (upstream of Talbingo Reservoir at O'Hares Picnic Ground), Jounama Creek (a tributary of Jounama Pondage just upstream of Jounama Campground), in Adjungbilly Creek (at Kangaroo Mountain Road), and McGregors Creek and Janeys Creek (tributaries of Blowering Reservoir) just north of Talbingo) (Lintermans, 2019). Redfin perch have also been caught in Talbingo Reservoir, Jounama Creek, Khancoban Pondage and in the Swampy Plains River near Youngal Station (approximately 8 km upstream of Khancoban Pondage) (NSW DPI, 2017b). They were also caught in Talbingo Reservoir, Yarrangobilly River and Wallaces Creek (approximately 4 km upstream of Talbingo Reservoir) as part of this assessment (**Section 5.2**).

Redfin perch are present in the Murrumbidgee River upstream to the ACT/NSW border. It appears that a series of natural barriers, such as shallow cascades and waterfalls, present in this section of river prevent its movement upstream from the ACT. Redfin perch are considered absent from the Upper and Mid Murrumbidgee River Catchment and from Tantangara Reservoir. This was supported the targeted eDNA survey for redfin perch, which detected DNA within the weirpool just upstream of Angle Crossing, but not approximately 30 km upstream of here at Colinton (nor at any of the other seven sites on the Murrumbidgee River farther upstream or at sites in Tantangara Reservoir) (**Section 5.2.6**). Redfin perch DNA was not detected in the Geehi River, Lake Eucumbene, Jindabyne and T2 catchments (refer **Section 5.2.6**). They also appear to be absent from the Geehi River downstream of the dam, possibly due to natural barriers preventing movement upstream from Khancoban Pondage/Swampy Plains River. In the Snowy River Catchment, they are present as far upstream as Jindabyne Dam.

4.4.2 Eastern gambusia (*Gambusia holbrooki*)

Eastern gambusia is a small, stout fish with a deep rounded belly. It is generally greenish olive to brown on the dorsal surface and sides grey with a bluish/silvery sheen. Females can grow to around 60 mm in length, while the male only grows to about 35 mm (McDowell, 1996). Eastern gambusia is native to south-eastern United States of America. It is a highly invasive, major pest species within Australia and is listed as one of the 100 worst invasive species worldwide (Lowe et al., 2000). It prefers warm, gently flowing or still shallow water and is often found around the margins and along the edges of aquatic vegetation (McDowell, 1996). Although it may prefer warmer water, it is able to tolerate cold temperatures. It is highly tolerant of a wide range of salinities, from freshwater to marine. It is a live bearer, giving birth to live young as opposed to laying eggs. It is a highly fecund species, with around 50 to 100 fish produced per brood with up to nine broods in a year, with peak reproductive activity occurring around October (McDowell, 1996). Young are thought to mature in under two months. This rapid maturation, combined with large brood sizes allows populations to expand very rapidly (McDowell, 1996). It can behave aggressively towards other species by chasing and fin nipping, which can lead to secondary bacterial or fungal infections and potentially death of other fish. It is considered a generalist predator, with its diet consisting of a wide variety of food items including ants, flies, aquatic bugs and beetles (McDowell, 1996) but it can also prey upon the eggs and juveniles of other fish species and has been linked to the decline of frog species through predation of tadpoles and adult frogs. Due to its aggressive nature and high reproductive rate, it is thought to be able to outcompete native fish (Lintermans, 2018).

Eastern gambusia is widely distributed throughout NSW, Victoria and South Australia in both inland and coastal drainages, including the Murray-Darling Basin (McDowell 1996; Lintermans, 2019) and the Snowy River catchment (Gilligan & Williams, 2008) upstream to Jindabyne Dam. It has been recorded in the Murrumbidgee River in the ACT and as far upstream as Adaminaby (NSW DPI, 2017b; Lintermans, 2019) and in Gilmore Creek (a tributary of the Tumut River with a confluence downstream of Blowering dam wall) (Lintermans, 2019). It was detected in Talbingo Reservoir during the current assessment, but not in Yarrangobilly River, Wallaces Creek, Tantangara Reservoir or in tributaries of the Tantangara Reservoir (**Section 5.2**). Based on catch and eDNA survey data, there is an indication that eastern gambusia is not present in the Murrumbidgee River upstream of around Adaminaby. Eastern gambusia was not caught further upstream at Killarney by NSW DPI, (2017b) or just downstream of Tantangara Reservoir dam wall during the two electrofishing surveys undertaken for this assessment. DNA from eastern gambusia was detected downstream of Adaminaby but not upstream of this location. The most upstream known record of eastern gambusia is at Bolaro (NSW DPI, 2017b).

DNA from eastern gambusia was detected in Talbingo Reservoir, Jounama Reservoir and the Mid and Lower Murrumbidgee River catchments, but not in the Geehi River and Swampy Plains catchmentsor the Tumut River Catchment upstream of T2 Dam (**Section 5.2.6**).

Eastern gambusia DNA was detected in Lake Eucumbene and Lake Jindabyne, though the low rate of detection (a few percent of all samples collected) in the absence of previous records provides inconclusive evidence of their presence. Further work would be required to confirm the status of eastern gambusia in these lakes.

4.4.3 Wild goldfish (*Carassius auratus*)

Wild goldfish (goldfish) is a deep-bodied freshwater fish closely related to carp. They can reach up to 400 mm in length and weigh up to 1 kg, although they are more commonly observed at 100 mm to 200 mm (McDowell, 1996). Goldfish feed mostly on small shellfish and plant material. Goldfish prefer still or sluggish waters and can tolerate a wide range of environmental conditions, such as low dissolved oxygen and high water temperature. It matures at around 100 mm to 150 mm in length and spawns during the summer months. Large females can produce up to several hundred thousand eggs each season, often laid among aquatic plants (McDowell, 1996). Goldfish tend to feed on aquatic plant matter, organic detritus and small aquatic insects.

Goldfish is native to eastern Asia but is now widely distributed throughout the world. In Australia, this pest species is now widespread throughout much of NSW and Victoria, and large areas of South Australia and Western Australia. It occurs in many coastal streams and throughout the Murray-Darling Basin (McDowell, 1996). It has been identified by NSW DPI (2017b) and Lintermans (2019), and DNA from wild goldfish was detected in this study within the Murrumbidgee River around Cooma. NSW DPI collected goldfish within Talbingo Reservoir (NSW DPI, 2017b) and it was caught here during the current assessment (**Section 5.2**). Its DNA was also detected in Talbingo Reservoir and Jounama Pondage (**Section 5.2.6**), and records exist from the Lower Tumut Catchment (ALA, 2019). Based on existing literature, it appears that wild goldfish is not present in the Murrumbidgee River upstream of around Adaminaby. Wild goldfish was not caught further upstream at Killarney by NSW DPI (Fisheries) (NSW DPI, 2017b) or just downstream of Tantangara Reservoir Dam wall during the two electrofishing surveys and eDNA sampling undertaken for this assessment. The most upstream known record of wild goldfish is at Kissops Flat (NSW DPI, 2017b).

Wild goldfish are reported to occur in Lake Eucumbene and Lake Jindabyne and was caught further downstream in the Snowy River above and below Snowy Falls (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. April 2019). A record of wild goldfish in the Snowy River catchment also exists in the ALA database (ALA, 2019).

This species is known to be responsible for the transmission of diseases including Goldfish Ulcer Disease (GUD) (Lintermans, 2007). Since outbreaks of this disease have occurred in NSW and Victorian fish hatcheries and farms since 1974, NSW DPI have found that Murray cod, golden perch and silver perch are resistant to GUD, although it is stated that trout are at a high risk of infection. Trout cod and are also thought to be potentially at risk. Aside from this, impact of goldfish to native species are generally regarded as benign with few or no adverse impacts documented (Lintermans, 2007).

4.4.4 Carp (*Cyprinus carpio*)

Carp is a large introduced freshwater fish that is common throughout most of NSW (McDowell, 1996). It is considered a pest due to its destructive bottom-feeding habits, which stir up sediments and affect water quality. It can attain a very large size, with overseas reports of specimens up to 1.2 m in length and weighing around 60 kg. Carp up to 10 kg have been reported in south-eastern Australia but is more commonly observed at around 5 kg (McDowell, 1996). Its colour can vary, although in the wild it tends to be olive green to bronze/silver with a paler underbelly. One of its prominent features is a pair of barbels, with each barbel located at the corners of its mouth. Carp prefers still or gently flowing water, generally where aquatic vegetation is abundant. It is a very tolerant species, being able to withstand very low dissolved oxygen and highly turbid environments that allow it to establish in stagnant waters not often inhabited by other fish species. Spawning season occurs in spring (September to December) and is dependent on water temperature, with ideal conditions occurring between 17°C and 25°C. Carp matures early (1 to 2 years) and is very fecund, with females over 6 kg able to produce up to 1.5 million eggs (McDowell, 1996). The sticky eggs are deposited on fibrous plant matter in shallow water over several days, with eggs hatching after only a few days. It has a highly varied diet including molluscs, crustaceans, insect larvae and seeds. If food in the water column is scarce, a Carp can suck soft plant matter and detritus from the substratum to feed. This method of feeding has the potential to increase concentrations of suspended sediment (which can then affect other organisms and processes within the aquatic environment) (NSW DPI, 2019c). Carp have been linked to several other impacting processes, such as algal blooms and increased erosion, and have been linked to reductions in numbers of native fish (NSW DPI, 2019c). Carp is native to central Asia but has been introduced to many countries and is now thought to be the most widely distributed fish worldwide. In some countries in Europe and Asia, it is farmed extensively, whilst in places such as North America, Canada and Australia, Carp is considered a significant pest species (McDowell, 1996).

It is widespread throughout the Murray-Darling Basin and has been reported in the Murrumbidgee River as far upstream as Cooma and in tributaries of the Tumut River downstream of Blowering dam wall (Lintermans, 2019; ALA, 2019). NSW DPI also recorded carp within the Murrumbidgee River near Cooma (NSW DPI, 2017b) and in the Tumut River system downstream of Talbingo Reservoir (in a number of tributaries of the Tumut River) (ALA, 2019). Sightings have also been recorded from Blowering Reservoir. Carp appear to be absent from Lake Eucumbene and Lake Jindabyne, and although a single carp was caught in the Snowy River below Dalgety Weir (Graham, et al., 2005), it was not identified from the Snowy River by (Gilligan & Williams, 2008) and carp is considered largely absent from the Snowy River catchment (Luke Pearce, NSW DPI (Fisheries), Pers. Comm. April 2019). Khancoban Pondage and upstream was reported to be free of Carp (Graham, et al., 2005). An online report exists of a carp just downstream of the dam wall (Feral Scan, 2019).

DNA from carp was detected in Talbingo Reservoir in low relative abundance. Carp were not caught here (or anywhere else in the study area) using gill nets or boat-based electrofishing. As discussed in **Section 6,** by itself, DNA detections at low relative abundance is considered insufficient to consider a species to be present. It is considered more likely that this detection represented transfer of carp DNA from outside study area, rather than live individuals within the reservoir (**Section 5.2.6**).

4.4.5 Oriental weatherloach (*Misgurnus anguillicaudatus*)

The oriental weatherloach is a highly adaptive species able to outcompete native species (McDowell,1996). It can tolerate low dissolved oxygen and has the ability to swallow air and use atmospheric oxygen. It is able to burrow to escape predators, and move overland to disperse and colonise new water bodies. It has been recorded in the Murrumbidgee River as far upstream as the ACT/NSW border (Biosis, 2009; Lintermans, 2019), Bumbalong Road (NSW DPI, 2017b) and Bredbo (ALS, 2011) and in tributaries of Lake Eucumbene. There is also an unconfirmed report from the Peak River in the Tumut River Catchment below Blowering Dam wall in (Koster, et al., 2002). It is considered absent from Talbingo and Tantangara reservoirs and was not detected in any surveys of this project. Oriental weatherloach is a notifiable species under the NSW Biosecurity Regulation 2017.

4.4.6 Salmonids

Several species of salmonid occur in the Murray-Darling Basin and Snowy River Catchment. These include brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*). The most widespread and abundant of these are brown trout and rainbow trout, which are considered present throughout all catchments within the study area (the one exception is the upper Tantangara Creek, where they are not found upstream of the waterfall upstream of Alpine Creek Trail). Both species have been caught throughout the Murrumbidgee River, the Tumut River (including Talbingo Reservoir), Snow River and Murray River Catchments (NSW DPI, 2017b; Lintermans 2018). These are primarily maintained via stocking and potentially via natural recruitment in upstream reaches. The populations in Tantangara Reservoir and connected watercourses in the upper Murrumbidgee Catchment are sustained by natural recruitment only as they are not stocked here. Atlantic salmon and brook trout are also stocked in Lake Jindabyne with Atlantic salmon also stocked in the Swampy Plain River and brook trout in Three Mile Dam and Thredbo River. Brown trout and rainbow trout have had a serious impact on the distribution and abundance of the native galaxiid species in south-eastern Australia, such as mountain galaxias (MDBA, 2009). Atlantic salmon were stocked previously in Talbingo Reservoir and Jounama Pondage but not since 1982 and these fish would almost certainly not be present in these areas now (Gilligan, 2005).

4.5 Key Fish Habitat

Talbingo and Tantangara Reservoirs and each of the watercourse listed in **Table 2-1** are designated as key fish habitat (KFH) in the Tumut, Snowy River and Murrumbidgee LGAs (NSW DPI, 2019d). Different 'types' of KFH and waterway classes are described in Section 3.6.3 (**Tables3-2** and **Table 3-3**) of the Aquatic Ecology Assessment report and outlined in Fairful, (2013).

4.6 Pathogens and Other Aquatic Pests

Based on the NSW Aquatic Pest and Disease Distribution map, several aquatic pests and one known disease have been identified in the Murrumbidgee River Catchment.

Lernaea spp. (anchor worms), an exotic copepod (small crustacean), was suspected to occur in the catchment although no formal records are known. This genus of ectoparasite attaches to the skin, gills or sometimes the buccal cavity of the fish. In lentic environments burrowing into the fish can occur (Khalifa & Post, 1976). Fish can produce an inflammatory response in the dermis and musculature to the activities of this copepod and, in advanced cases, necrosis (Joy & Jones, 1973; Khalifa & Post, 1976). It often infests wild goldfish (MDBC, 2007d), carp, redfin perch and farmed silver perch but can also infect tadpoles, Murray cod and trout. The fate of the host is dependent on the site of penetration and severe infestations could result in, or contribute to, mortality. Outbreaks of parasites from this genus have been linked to increased water temperatures and reduced flow (Kupferberg, et al., 2009). Carp and redfin perch have been suggested the source of this parasite in Australia (Lintermans, 2002). Goldfish in the Canberra region are often heavily infested.

EHNV is an Australian type of iridovirus that is known to infect and be spread by wild populations of redfin perch and farmed rainbow trout. This strain also has the potential to negatively impact several native fish species of the Murray-Darling Basin. The virus enters fish through the body surface or gastrointestinal tract, multiplies in the blood forming organs such as the spleen and kidney and destroys them in the process, the liver is also affected by the virus. Most infected fish are believed to quickly succumb and die. EHNV poses no known threat to humans. There have been no reported incidences of fish kills associated with EHNV in Talbingo Reservoir and it is unknown if the disease occurs here, although there have been confirmed outbreaks in nearby Blowering Reservoir (Whittington et al., 2011). EHNV is a notifiable disease under the NSW Biosecurity Regulation 2017.

Hick, et al*.,* (2019) undertook a review of the current knowledge of EHNV in Australia and an assessment of the potential for its distribution to increase as a result of Snowy 2.0 Main Works. The findings of this study were incorporated into the aquatic impact assessment.

Neither anchor worms, nor EHNV have been identified within Tantangara or Talbingo Reservoir or any other watercourses included in the project area.

4.7 Phytoplankton

4.7.1 Background

Phytoplankton are photosynthetic microscopic organisms (primary producers) that form the basis of aquatic food webs, providing an essential ecological function for all aquatic life. Being photosynthetic organisms, they live in the euphotic zones (well-lit surface layers) of waterbodies and account for almost half of all photosynthetic activity worldwide (Behrenfeld, et al., 2001; Field, et al., 1998). They are also a vital component of carbon and nutrient cycles in aquatic environments and are therefore important to chemistry and biology. It has been estimated that phytoplankton are responsible for over 50% of the world's oxygen production via photosynthesis (Behrenfeld, et al*.,* 2001; Walker, 1980) and as a result, play a large role in the atmospheric CO_2/O_2 balance (Igamberdiev and Lea, 2006; Tappan, 1968).

Like other photosynthetic organisms, they rely on carbon dioxide, nutrients (nitrogen and phosphorus) and sunlight for growth and development, and are susceptible to changes in water temperature, pH, salinity and water depth (Evtimova and Donohue, 2014; Zohary and Ostrovsky, 2011). Phytoplankton typically range in size from 0.002 mm to 1 mm and include diatoms, dinoflagellates, Radiolaria, Ciliata and Cyanobacteria (better known as 'blue-green algae').

The presence of blue–green algae can lead to water quality problems as some species are capable of producing toxins which are generally contained within the blue–green algal cell but may be released into the water when the cell is damaged or dies. Toxic cyanobacteria are found worldwide in inland and coastal water environments. At least 46 species have been shown to cause toxic effects in vertebrates (Sivonen and Jones 1999) with the most common toxic cyanobacteria in fresh water being *Microcystis* spp., *Cylindrospermopsis* *raciborskii*, *Planktothrix* (syn. Oscillatoria) rubescens, Synechococcus spp., Planktothrix (syn. Oscillatoria) agardhii, Gloeotrichia spp., *Anabaena* spp., *Lyngbya* spp., *Aphanizomenon* spp., *Nostoc* spp., some *Oscillatoria* spp., *Schizothrix* spp. and *Synechocystis* spp. (WHO 2003). According to the World Health Organisation (WHO), toxicity cannot be excluded for further species and genera and as research broadens additional toxic species are likely to be found. As a precaution, toxic potential in any cyanobacterial population should not be ruled out (WHO 2003). The WHO has developed a range of guidelines relating to low, medium and high probabilities of adverse health effects. For example, a guideline level of 20,000 cyanobacterial cells/mL has been determined for a low level probability of adverse health effects (Pilotto et al., 1997).

Over growth by blue–green algae can also reduce light penetration to other aquatic plants and may lead to their death. When aquatic plants and algae die, oxygen is consumed during decomposition decreasing dissolved oxygen and potentially leading to the death of fish and other aquatic biota (WaterNSW 2019).

Given their importance to aquatic ecosystems, changes to the abundance and/or composition of phytoplankton assemblages within a waterbody can alter the biological and chemical behaviour of these waterbodies.

4.7.2 Long-term Data

Phytoplankton data have been collected within Talbingo and Tantangara Reservoirs by Snowy Hydro as part of an ongoing monitoring program since 1998 (multiple times per year) and include data on total phytoplankton levels, and on key phytoplankton taxa such as Cyanophyta (blue-green algae), Bacillariophyceae (diatoms), Chlorophyta (green algae), Chrysophyceae (golden algae), Cryptophyceae, Euglenophyta and Pyrrophyta. The data examined within this report were collected from the following sites:

- Talbingo Reservoir:
  - Tal N near the dam wall (SHL ref: 41015721);
  - Tal S near the confluence of the Tumut and Yarrangobilly Rivers (SH ref: 41015723);
- Tantangara Reservoir
  - Tan N near the confluence of the Murrumbidgee River and Nungar Creek (SH ref: 41015432); and
  - Tan S near the dam wall (SHL ref: 41015431).

Examination of the data collected by Snowy Hydro indicated the average phytoplankton abundance (measured as cells/mL) is generally greater in Tantangara Reservoir compared with Talbingo Reservoir (**Figure 4-1**).

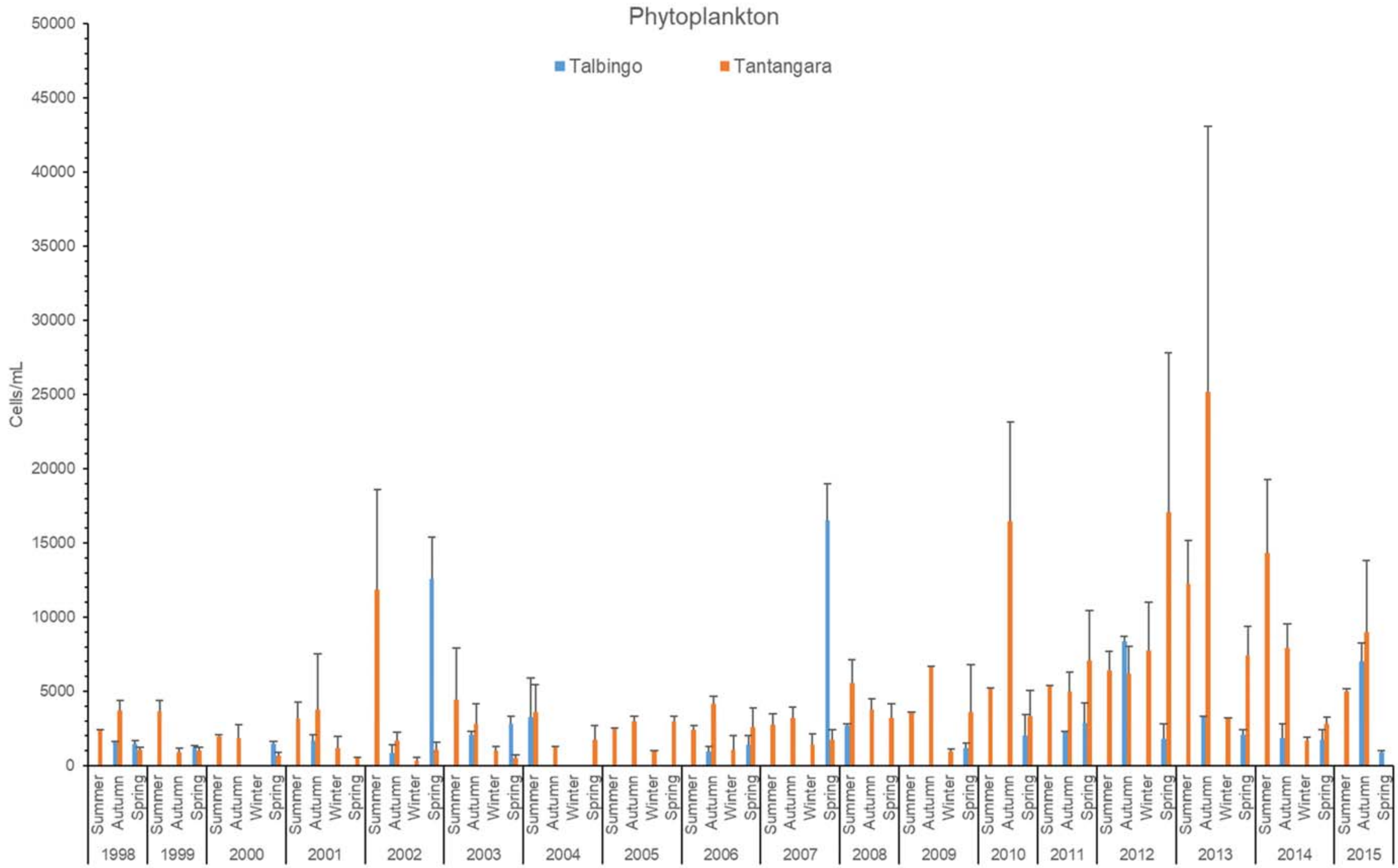


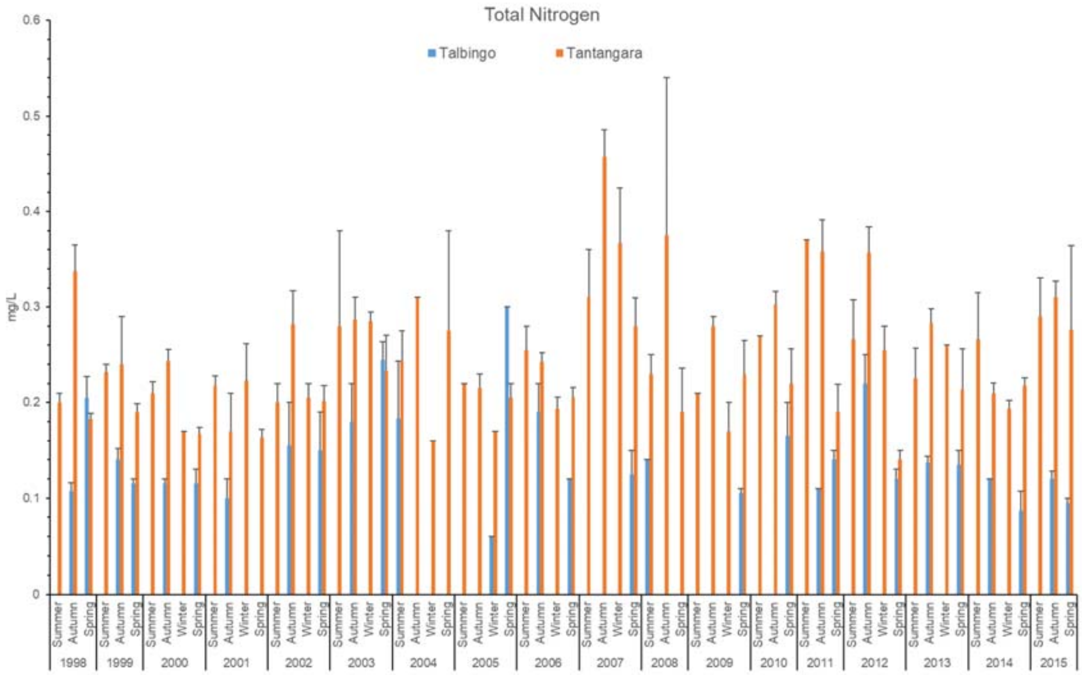
Figure 4-1 Mean phytoplankton abundance (±SE) within Talbingo and Tantangara reservoirs between 1998 to 2015.

Phytoplankton abundance in samples from Tantangara Reservoir appear to have increased since 2010, with levels often over 7,000 cells/mL. Prior to 2010, average phytoplankton abundance was generally below 5,000 cells/mL. In comparison, phytoplankton levels sampled from Talbingo Reservoir have generally been below 3,000 cells/mL throughout much of the monitoring program, although exceeded 5,000 cells/mL on a number of occasions over time (**Figure 4-1**). It should be noted that the sampling regime in Tantangara is much more frequent than in Talbingo, which may affect comparisons of these results.

Total nitrogen (TN) and total phosphorus (TP) levels can significantly influence and increase phytoplankton abundance and both are often substantially greater within Tantangara Reservoir compared to Talbingo Reservoir (**Figure 4-2**). The increase in phytoplankton abundance measured in Tantangara Reservoir since 2010 did not correspond to any increases in TN or TP throughout this period, with post-2010 TN and TP levels remaining relatively similar to pre-2010 levels in Tantangara Reservoir.

Further examination of the historical data indicates that the composition phytoplankton assemblages in each reservoir differs from one another. Chlorophyta contribute approximately 45% of the phytoplankton abundance in each reservoir, although a greater percentage of Cyanophyta are often present within Talbingo Reservoir (38% compared to 19% within Tantangara Reservoir), whilst a greater percentage of Bacillariophyta are usually present within Tantangara Reservoir (30% compared to 15% within Talbingo Reservoir) (**Figure 4-3**). These three taxa contribute more than 95% of the phytoplankton assemblage within each reservoir.

(a)



(b)

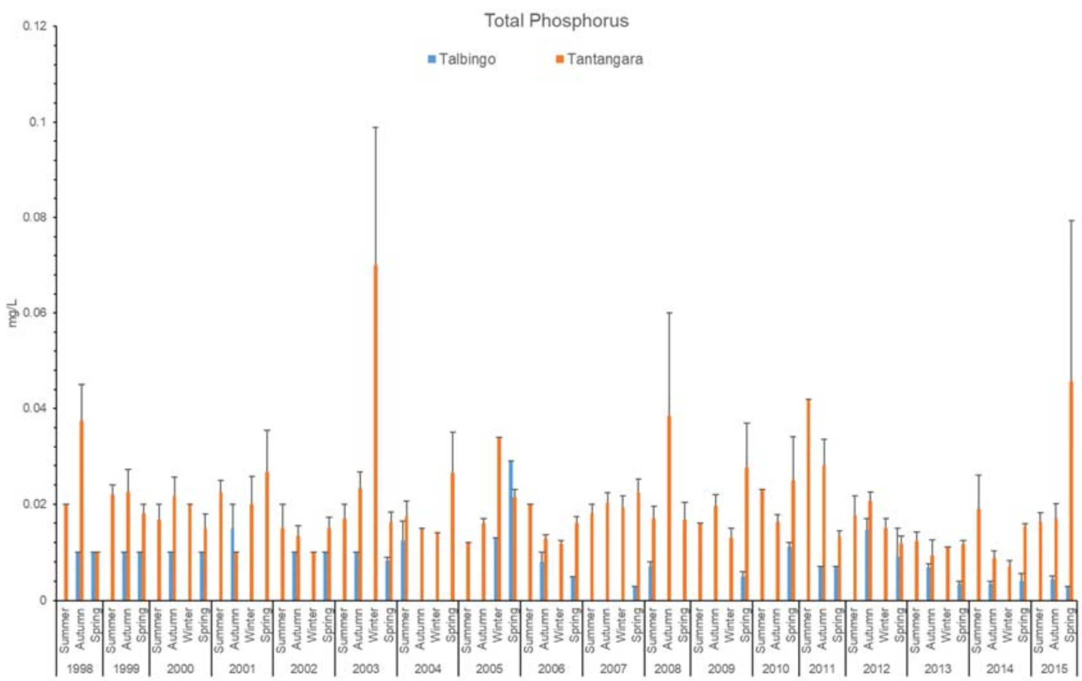


Figure 4-2 Mean (a) Total Nitrogen (TN) and (b) Total Phosphorus (TP) levels (±SE) in Talbingo and Tantangara reservoirs between 1998 to 2015.

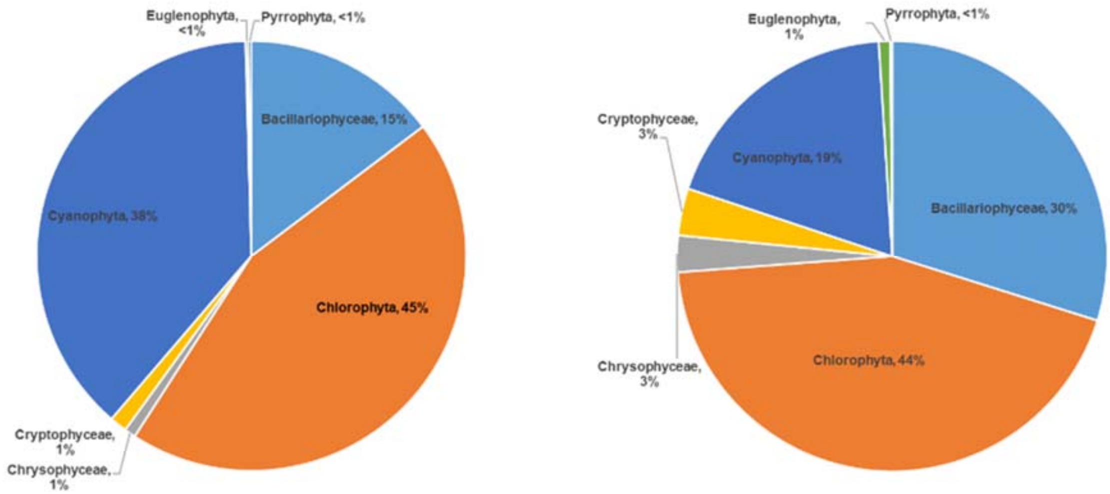


Figure 4-3 Phytoplankton assemblage composition in Talbingo and Tantangara reservoirs based on long-term data collected by Snowy Hydro from 1998 to 2015.

The composition of phytoplankton assemblages can also vary (sometimes quite considerably) among seasons both within and between each reservoir (**Table 4-1**). For example, the percentage contribution of Cyanophytes within Tantangara Reservoir typically increases in autumn to around 35% then decreases throughout winter and spring (to below 10%) before increasing again in the summer period.

Table 4-1 Percentage contribution of each phytoplankton taxa to the overall phytoplankton abundance in Talbingo and Tantangara reservoirs for each season where data were available.

Taxa	Summer		Autumn		Winter		Spring	
	Talbingo	Tantangara	Talbingo	Tantangara	Talbingo	Tantangara	Talbingo	Tantangara
Bacillariophyceae	12.45	33.44	18.72	23.43	ND*	29.58	12.62	42.11
Chlorophyta	45.61	46.42	42.31	38.45	ND	47.14	46.23	41.37
Chrysophyceae	0.74	3.87	1.04	1.17	ND	1.55	0.80	5.82
Cryptophyceae	1.14	2.53	1.57	3.07	ND	10.14	1.11	2.87
Cyanophyta	39.59	12.94	35.90	32.48	ND	11.19	39.02	7.26
Euglenophyta	0.21	0.70	0.19	1.32	ND	0.48	0.16	0.57
Pyrrophyta	0.32	0.13	0.08	0.10	ND	0.28	0.03	0.05

*ND = no data.

5 Field Survey Results

5.1 Aquatic Habitat and Plants

5.1.1 Talbingo Reservoir

The following aquatic habitats were identified within Talbingo Reservoir:

> Unvegetated soft sediment;
> Aquatic macrophytes;
> Submerged timber;
> Rocky rubble; and
> Open water

Although soft sediment is the dominant aquatic habitat present within Talbingo Reservoir (in both deep and shallow water), submerged timber (or wood debris) is also extensive throughout as a result of damming and inundation of the forested river valley. Wood debris consists of full trees, trunks and branches still rooted within the reservoir bed, as well as branches and tree stumps. Beds of aquatic macrophytes were observed in the shallower margins of the reservoir, particularly within the lower Yarrangobilly River and Middle Creek areas. It appears that the distribution and abundance of these macrophytes are seasonal in nature, generally present (sometimes in large, dense beds) during the warmer months of the year when water temperatures are ideal for growth.

Submerged macrophytes and algae were observed at most locations visited during the mapping surveys undertaken within Talbingo Reservoir in January and March 2019. Species included:

> *Elodea canadensis* (Canadian pondweed) (exotic);
> *Potamogeton ochreatus* (Blunt pondweed);
> *Potamogeton crispus* (Curly pondweed); and
> *Nitella* sp. (not identified as the threatened *Nitella* sp.)

Large, dense beds of exotic *Elodea* were observed within the Yarrangobilly River and Middle Arm, which formed thick mats that grew to around 5 m water depth in some places (**Figure 5-2**). Scattered amongst these mats were long strands of *Potamogeton ochreatus,* which were quite prominent at both of these locations (**Figure 5-2**).

In Ravine Bay and Middle Creek, large areas of *Elodea* and the green alga, *Nitella*, grew along the shoreline out to around 8 m water depth. This growth formed a relatively continuous mat of aquatic vegetation that extended throughout the shallow regions of the bay and creek (**Figure 5-2**). Interspersed sporadically within the dominant *Elodea* beds in these areas were small, isolated strands of *Potamogeton crispus.*

Macrophytes within Plain Creek Bay mostly consisted of *Elodea* with some small patches of *Nitella*. The *Elodea* was in high density (> 50% cover) throughout some of the shallower margins of the bay, however, lower densities were evident further from shore where it reached a maximum water depth limit of around 9 m.

Similarly, macrophytes within Cascade Bay showed a similar growth pattern to those observed within Plain Creek Bay, with *Elodea* the dominant macrophyte, although it did not appear to be as widespread compared with Plain Creek Bay. *Nitella* was also observed within a number of transects, sometimes in quite high densities but tended to be patchy in distribution.

Where dense beds occur, *Elodea* can be problem as it chokes channels and depletes dissolved oxygen levels, potentially affecting native aquatic species. As it can reproduce by fragmentation, it can also spread from an infested waterbody to a weed free waterbody by attaching to watercraft, trailers and fishing equipment (DPI, 2015). *Elodea* can withstand freezing and grow rapidly when water temperature exceeds 15 °C (DPI, 2015) and has a high light requirement for optimum growth but does not thrive in iron-deprived water (DPI, 2015).

No macrophytes were observed at the northern end of the reservoir towards the spillway with the substratum generally consisting of rocky rubble. High density *Nitella* was observed, however, to the north-east of the swimming area on the north-western shoreline of the reservoir down to around 8 m water depth.

Two species of *Nitella* are listed as threatened under the NSW *Biodiversity Conservation Act 2016* (BC Act) (*Nitella partita* and *Nitella parooensis*). Based on known distributions of these species, it is highly unlikely that the *Nitella* observed within Talbingo Reservoir is either of these two species. *Nitella partita* is only found in some wetlands of north-western NSW (present in the Central Darling Local Government Area and Unincorporated Area), whilst *Nitella parooensis* is currently known to occur in three small temporary freshwater wetlands within the Paroo River Catchment in the Nocoleche Nature Reserve (north-western NSW).

The distribution and abundance of these macrophytes appears to be seasonal in nature, generally present (sometimes in large, dense beds) during the warmer months of the year when water temperatures are ideal for growth. A map showing the presence of submerged macrophytes within Talbingo Reservoir is in **Figure 5-1**. Images of the submerged habitat types are in **Figure 5-2**.

The biota of the open water habitat of the reservoir range in size from single-celled (algae and dinoflagellates) to multi-cellular organisms such as fish.

5.1.2 Tantangara Reservoir

The natural setting and topography of the Tantangara Reservoir catchment is quite different from Talbingo Reservoir, with much of it situated within a flat, alpine plateau region. As a result, vegetation surrounding the reservoir consists of mostly native grasses and tussocks with low profile heath type habitat.

Aquatic habitat present within Tantangara Reservoir includes mostly:

- Unvegetated soft sediment;
- Drowned grass tussocks and shrubs;
- Rocky rubble;
- Rock boulders and emergent bedrock;
- Rocky rubble; and
- Open water.

Soft sediment dominates the benthic habitat within the reservoir with only small outcrops of rocky rubble existing throughout. During the dedicated mapping survey undertaken in March 2019, no aquatic vegetation was observed within Tantangara Reservoir. During a field survey in January 2019 to sample sediments, a small patch (approximately 10 m^2) of *Elodea* was incidentally observed along the eastern shoreline within the shallow margins (**Figure 5-1**). This area was again visited during the targeted macrophyte survey undertaken in March 2019, but no aquatic vegetation was observed.

The reservoir level at the time of the targeted survey was lower than the water level witnessed in January 2019, with some of the area that was previously covered by the *Elodea* exposed due to the lower water levels. It appeared that the *Elodea* previously seen in this area was decaying, with only dead stems and rhizomes with no leaf growth. Water clarity at the time of the survey in March 2019 was poorer than observed during previous field surveys within the reservoir, which may have contributed to the disappearance of the macrophyte patch in response to reduced light levels.

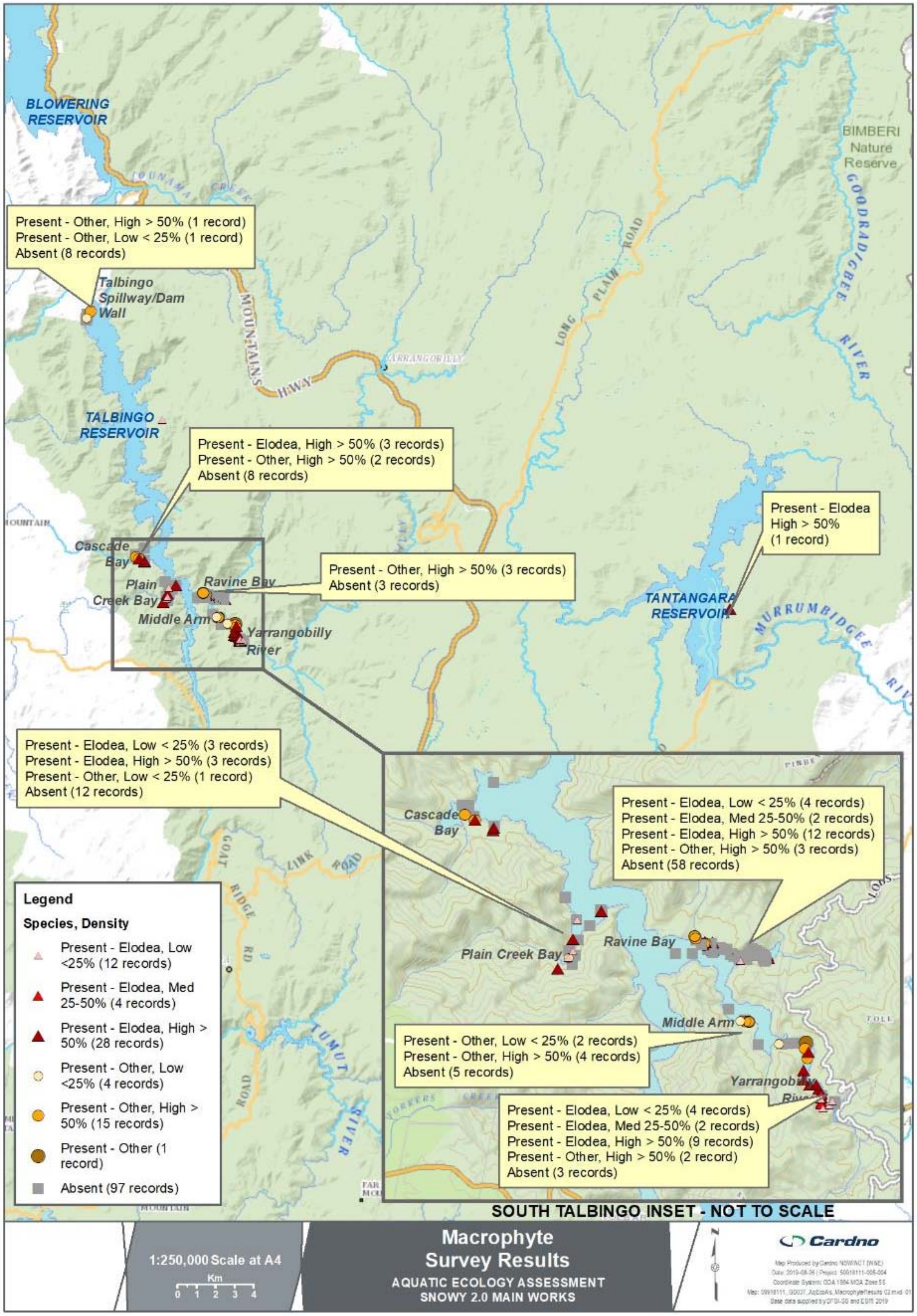


Figure 5-1 Macrophyte survey results Talbingo Reservoir.

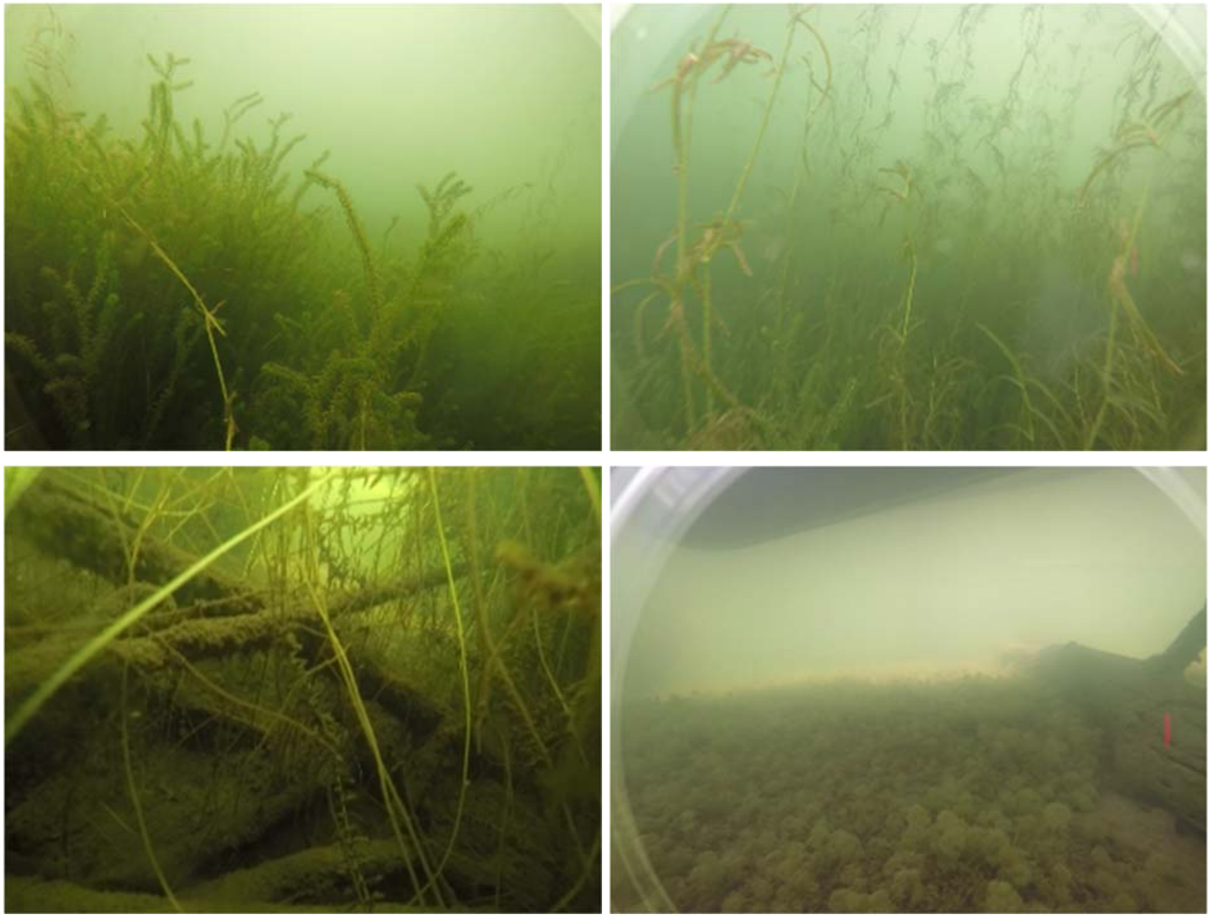


Figure 5-2 (a) Dense beds of *Elodea* within Middle Arm. (b) *Elodea* bed with *Potamogeton* growing to the surface in Middle Arm. (c) Dense *Elodea* within submerged timber. (d) Extensive area of *Nitella* within Ravine Bay.

5.1.3 Watercourses

The habitat attributes of each watercourse surveyed, KFH type and stream classifications are in **Table 5-1.**

Table 5-1 Summary of aquatic habitat of watercourses.

Watercourse (incl. Pools Disconnected to Main Channel)	Sites	Stream Order	Flow Type	Waterway Class (1 to 4)	Aquatic Habitat. Inc. Sensitive KFH and Type (1 to 3)	Channel / Pool Width	Riparian Vegetation	Substratum	Aquatic Plants * Identifies non-native taxa
Yarrangobilly River Catchment									
Yarrangobilly River	1a, YR1, YR2	>3	Per.	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Wood debris > 0.3 m diameter ▪ Habitat of threatened species (Murray crayfish)	5-10 m	Large trees > 10 m tall, generally continuous, mixed native and non-native species (Inc. blackberry and poplar)	Bedrock, Boulder, Cobble, Pebble with smaller amounts of gravel and sand	None observed at sites visited, but likely present in low abundance
Wallace's Creek	2a	>3	Per.	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Wood debris > 0.3 m diameter	1-3 m	Large trees > 10 m tall, continuous and native	Boulder, Cobble, Pebble with smaller amounts of	None observed at sites visited, but likely present in low abundance

Watercourse (incl. Pools Disconnected to Main Channel)	Sites	Stream Order	Flow Type	Waterway Class (1 to 4)	Aquatic Habitat. Inc. Sensitive KFH and Type (1 to 3)	Channel / Pool Width	Riparian Vegetation	Substratum	Aquatic Plants * Identifies non-native taxa
					▪ Habitat of threatened species (Murray crayfish)			gravel and sand	
Lick Hole Creek / Gully	4	3	Non Per.	3	Type 3 Very limited habitat	0.5 m	Large trees and grasses, encroaching on channel	Dense terrestrial vegetation, likely gravel / silt. Ford at site	None
Sheep Station Creek	10	>3	Non. Per. (Dry)	3	Type 3	1 m	Large trees, dense undergrowth	Cobble / pebble	None
O'Hares Creek	13	>3	Non Per.	3	Type 3 (consisted of a series of disconnected pools with no surface flow during visit)	1-2 m	Large trees, shrubs	Bedrock, boulder, cobble	Green filamentous algae
Upper Murrumbidgee Catchment									
Upper Murrumbidgee River	9a, 9b, MR1	>3	Per.	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Aquatic plants ▪ Gravel beds	3-6 m	Largely undisturbed grasses and heath	Bedrock, boulder, cobble, pebble, gravel, sand	*Potamogeton tricarinatus*
Tantangara Creek	8, 22, TC1, TC2, TC3, TC4	>3	Per.	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Aquatic plants ▪ Gravel beds	1-6 m	Largely undisturbed grasses and heath	Bedrock, boulder, cobble, pebble, gravel, sand	*Myriophylum* sp.
Tributary of Tantangara Creek	TCA1/2	3	Per.	1	Type 1: ▪ Gravel beds	1-2 m	Largely undisturbed grasses and heath	Bedrock, boulder, cobble, pebble, gravel, sand	*Myriophylum* sp.
Pools*	TC Pool 1	na	na	na	Type 3 KFH 0.1 m to 0.2 m deep	1-10 m	Largely undisturbed grasses and heath	Silt	None
Gooandra Creek	5, GC1, GC2, GC3	>3	Per	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Aquatic plants	1-2 m	Largely undisturbed grasses and heath	Bedrock, boulder, cobble, pebble, gravel	*Myriophylum* sp. (smaller patches along creek edge)
Pools*	GC Pool 1	na	na	na	Type 3 KFH 0.1 m to 0.5 m deep	1-10 m	Largely undisturbed grasses and heath	Silt	*Myriophylum* sp.
Nungar Creek	16, NC1, NC2, NC3	>3	Per.	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Aquatic plants ▪ Gravel beds	2-5 m	Largely undisturbed trees, shrubs/heath	Boulder, cobble, pebble, gravel, sand	*Myriophylum* sp.
Northern Tributary of Nungar Creek	NCA	3	Non. Per	2	Type 2	0.5 m	Largely undisturbed grasses and heath	Pebble, gravel	None

Watercourse (incl. Pools Disconnected to Main Channel)	Sites	Stream Order	Flow Type	Waterway Class (1 to 4)	Aquatic Habitat. Inc. Sensitive KFH and Type (1 to 3)	Channel / Pool Width	Riparian Vegetation	Substratum	Aquatic Plants * Identifies non-native taxa
Southern Tributary of Nungar Creek	NCB	3	Non. Per.	3	Type 3	0.5 m	Largely undisturbed grasses and heath	Gravel, sand, silt	None
Pools	NC Pools 1, 2 and 3	na	na	na	Type 3 KFH 0.1 m to 0.5 m deep	1-10 m	Largely undisturbed grasses and heath	Silt	*Potomogeton* sp. in some larger pools
Mufflers Creek	6	3	Per.	1	Type 2	0.5 to 2 m	Largely undisturbed, trees and grasses	Cobble, pebble	
Kelly's Plain Creek	7	3	Per.	1	Type 2 (although non-indigenous rocks > 0.5 m at Site 7))	1-2 m	Largely undisturbed, trees, and grasses	Cobble, pebble	None
	23	3	Non Per.	2	Type 2	1 m	Largely undisturbed, trees and grasses	Cobble, pebble	None
Bally Creek	17	>3	Per.	1	Type 1: ▪ Aquatic plants	1-2 m	Largely undisturbed, trees and grasses	Cobble, pebble, gravel	*Nymphoides geminate* *Potamogeton tricarinatus*
Ghost Gully	15	3	Non Per.	1	Type 1: ▪ Aquatic plants	1 m to 2 m	Largely undisturbed, trees and grasses	Cobble, pebble, gravel, silt	*Myriophylum* sp.
Lake Eucumbene Catchment									
Eucumbene River	14, EFR3	>3	Per.	1	Type 1: ▪ Rocks > 0.5 m diameter ▪ Aquatic plants ▪ Gravel beds	2-6 m	Largely undisturbed grasses and heath	Cobble, pebble, gravel	*Myriophyllum crispatum* *Myriophyllum caput-medusae* *Ranunculus trichophyllus** *Ranunculus* sp.* *Ranunculus inundates* *Callitriche* sp. / *Crassula* sp.
	24	3	Per	1	Type 1: ▪ Rocks > 0.5 m diameter	1-2 m	Largely undisturbed grasses and heath	Cobble, pebble, gravel	*Ludwigia palustris**
	EFR1, EFR2	3	Per	1	Type 1**	1 m		Pebble, gravel	*Batrachium trichophyllum**
Three Mile Creek	12, TMC1 TMC2	>3	Per.	2	Type 1**	1 m	Grasses	Cobble, pebble, gravel	None
Gang Gang Creek	21	>3	Per.	1	Type 1**: ▪ Aquatic plants	1 m	Largely undisturbed trees and grasses	Cobble, pebble, gravel	*Myriophyllum caput-medusae*

Watercourse (incl. Pools Disconnected to Main Channel)	Sites	Stream Order	Flow Type	Waterway Class (1 to 4)	Aquatic Habitat. Inc. Sensitive KFH and Type (1 to 3)	Channel / Pool Width	Riparian Vegetation	Substratum	Aquatic Plants * Identifies non-native taxa
Chance Creek	CC1	>3	Per.	3	Type 1**:	1 m	Largely undisturbed grasses and heath	Pebble, gravel	*Myriophyllum caput-medusae*
Alpine Creek	AC1	>3	Per.	3	Type 1**:	1 m	Largely undisturbed trees and grasses	Pebble, gravel	*Myriophyllum caput-medusae*
Rocky Plain Creek	RP1	>3	Per.	3	Type 1**:	1 m	Largely undisturbed trees and grasses	Pebble, gravel	*Myriophyllum caput-medusae*
Mid Murrumbidgee River Catchment									
Camerons Creek	CC1	>3	Int.	3	Not KFH Isolated pools	2 m	Grass, pasture	Silt, gravel	None
Camerons Creek Trib	CCA1	1	Eph.	3	Not KFH Farm dams	1 m	Grass, pasture	Silt, gravel	None
Goorudee Rivulet Trib	GRA1		Eph.	3	Not KFH	1 m	Grass, pasture	Silt, gravel	None
Cooma Creek Tributary	CoCA1	>3	Eph.	3	Not KFH None, dry	1 m	Grass	Terrestrial	None

*Ephemeral pools disconnected from the main creek channel, apparently derived from rainfall. **Type 1 Highly Sensitive KFH due to sites being located within the Snowy River EEC.

5.1.3.2 Yarrangobilly River Catchment

Yarrangobilly River and Wallaces Creek are perennial and provide substantial aquatic ecological value. Stream substratum consists of unconsolidated boulder, cobble, pebble and gravel with little evidence of siltation. This substratum could provide important spawning habitat for many native species, including galaxiids and Macquarie perch, if present. Watercourse edges were well vegetated with riparian plants including several mature trees apart from non-native blackberry which was present along Yarrangobilly River. No natural or artificial barriers to fish passage were identified on the surveyed sections of Yarrangobilly River and Wallaces Creek. Yarrangobilly River and Wallaces Creek support type 1 – Highly Sensitive KFH due to the presence of large rocks, large wood debris (in Yarrangobilly River) and the provision of habitat for a threatened species (Murray crayfish) in both watercourses. No aquatic plants were observed in the sections of these watercourses due to the fast flowing water and lack of fine sediment which discourages the establishment and growth of plants.

Tributaries of Wallaces Creek (Lick Hole Creek and Sheep Station Creek), were ephemeral and provided limited instream habitat value. In particular, Sheep Station Creek was dry at the time of sampling in February 2018. Only minimal flow was present in Lick Hole Creek. Cave Gully, a nearby tributary of Wallaces Creek, consisted of disconnected pools with no visible flow. These watercourses provide limited fish habitat, but would provide refuge for aquatic macroinvertebrates and potentially burrowing crayfish. O'Hares Creek (a tributary of Talbingo Reservoir) also consisted of a series of disconnected pools that would provide some habitat for fish and macroinvertebrates. These watercourses were classified as type 3 – Minimally Sensitive KFH due to their highly ephemeral flow and the absence of native aquatic plants.

Results of the aquatic habitat assessment using the RCE method are provided in **Attachment C**. Total scores ranged from 40 to 52, indicative of relatively undisturbed habitat. The only exception was Site 10 on Sheep Station Creek which was dry at the time of sampling and was not scored for riffle/pool sequence and aquatic vegetation. Site 10 otherwise scored highly (3 or 4) in each other category. The other sites scored highly 4 - no evidence of disturbance) in categories associated with the condition of riparian vegetation and/or channel morphology.

5.1.3.3 Upper Murrumbidgee River Catchment

Major watercourses to the west of the Upper Murrumbidgee River Catchment (Upper Murrumbidgee River and its tributaries Tantangara Creek and Gooandra Creek) are perennial and flow through alpine environments with a mixture of native and non-native sedges, grasses and shrubs. Tantangara Creek and Gooandra Creek are generally narrower and shallower than the Murrumbidgee River and flow over a mixture of cobble, pebble and gravel substratum with some boulders and bedrock and a few deeper pool sections. Areas of siltation (attributed to trampling of banks by wild horses) were observed in section of these watercourses. The section of the Upper Murrumbidgee River in this part of the Project area is wider (up to approx. 10 m) and consists of a series of shallow rifles and deeper pool sections. Native aquatic plants (*Myriophylum* sp. in Tantangara and Gooandra Creeks and *Potamogeton tricarinatus* in the Murrumbidgee River) were present in small isolated patches. Large rocks were also present in these watercourses.

Other smaller tributaries of the Upper Murrumbidgee River (Ghost Gully and Bally Creek) are similar in morphology and substratum composition to Gooandra Creek. *Myriophylum* sp. was present in Ghost Gully and Bally Creek which also support two other native aquatic plants (*Nymphoides geminate* and *Potamogeton tricarinatus*). Mufflers Creek, was also very similar to these watercourses, although no aquatic plants were observed in the section surveyed. Nungar Creek has a similar morphology to Tantangara Creek and a greater proportion of gravel and sand substratum. *Myriophylum* sp. was observed with large rocks and occasional gravel beds. Kelly's Plain Creek, did not contain aquatic plants or large rocks.

The Murrumbidgee River, Tantangara Creek (and tributary TCA1/2), Gooandra Creek, Nungar Creek, Bally Creek and Ghost Gully provide type 1 – Highly Sensitive KFH, due to the presence of native aquatic plants and large rocks and are classified as Class 1 waterways due to their perennial flow. The remaining watercourses (Mufflers Creek, Kelly's Plain Creek and the tributaries of Nungar Creek) provide type 2 - Moderately Sensitive KFH with the exception of NCB, which provides type 3 KFH due to its ephemeral flow. The pools associated with Gooandra Creek, Tantangara Creek and Nungar Creek provide type 3 KFH.

5.1.3.4 Lake Eucumbene Catchment

The Eucumbene River within the project area includes the upper few kilometres of river with its headwaters upstream of the Snowy Mountains Highway (Sites 24, EFR1 and EFR2). This section is relatively narrow (up to 1 m wide) and shallow, and at the time of survey in March 2019 consisted of a few centimetres of flow over pebble and gravel substratum with a few deeper (tens of centimetres) pools. A non-native aquatic plant, *Batrachium trichophyllum*, was present in this section. Further downstream at Sites 14 and EFR3 below the highway, the channel is wider (up to 6 m) with flow consisting of a series of riffles and pools over cobble, pebble, gravel and some boulder substratum. This section contained several native aquatic macrophytes including *Myriophyllum crispatum*, *Myriophyllum caput-medusae*, *Ranunculus inundatus*, *Callitriche* sp. / *Crassula* sp. and non-native *Ranunculus trichophyllus* and *Ranunculus* sp. The non-native *Ludwigia palustris* was also observed near Site 24 just upstream of the Snow Mountains Highway.

The several tributaries of the Eucumbene River visited (Three Mile Creek, Gang Gang Creek, Chance Creek, Alpine Creek and Rocky Plain Creek) are relatively narrow although appear perennial and support native *Myriophyllum caput-medusae*. Sites on Gang Gang Creek, Alpine and Rocky Plain Creek are located at lower elevations with riparian vegetation including large trees, compared with the alpine environment at the higher elevations where Three Mile Creek and Chance Creek are located.

All of these watercourses provide type 1 KFH – Highly Sensitive due the presence of native aquatic plants and/or their association with the Snowy River EEC, which includes these watercourses and provides endangered status to all associated species.

5.1.3.5 Mid Murrumbidgee River Catchment

The Murrumbidgee River downstream of Tantangara Reservoir dam wall provides type 1 KFH – Highly Sensitive. This is due to the presence of large rocks, wood debris, native aquatic plants (inferred) and the presence of threatened Macquarie perch (at least as far upstream as Yaouk Bridge).

5.2 Fish and Crayfish

5.2.1 Boat Based Electrofishing

Redfin perch and eastern gambusia were caught from Talbingo Reservoir at each location visited. The majority of redfin perch, (all juvenile) were caught amongst beds of *Elodea*. A few were caught amongst submerged timber. All eastern gambusia were caught amongst beds of *Elodea*. Wild goldfish were caught only within the Tumut River arm (at Sue City) amongst *Elodea*. A single Murray crayfish was caught below

FSL in a flowing section of Yarrangobilly River just upstream of the Talbingo dam supply level at the time of sampling.

Brown trout and rainbow trout were caught at each location in Tantangara Reservoir. The total number of fish species sampled using boat based electrofishing in Talbingo Reservoir and Tantangara Reservoir is in **Table 5-2**.

Table 5-2 Numbers of fish species caught using boat-based electrofishing in Talbingo Reservoir and Tantangara Reservoir.

Common Name	Scientific Name	Talbingo Reservoir	Tantangara Reservoir
Threatened Species			
Murray crayfish	*Euastacus armatus*	1*	
Non-native Species			
Redfin perch	*Perca fluviatilis*	200	
Eastern gambusia	*Gambusia holbrooki*	10	
Wild goldfish	*Carassius auratus*	30	
Rainbow trout	*Oncorhynchus mykiss*		50
Brown trout	*Salmo trutta*		100

*Caught above supply level in a flowing section of Yarrangobilly River

5.2.2 Gill Nets

5.2.2.1 Talbingo Reservoir

Thirty-one fish, including rainbow trout, brown trout and redfin perch were caught in gill nets over the three-day gill netting survey within Talbingo Reservoir in September 2018. Brown trout were the most abundant species recorded across the survey (16 individuals caught in total), followed by rainbow trout (nine individuals) and redfin perch (six individuals). The size of rainbow trout captured ranged between 28 cm and 44 cm fork length (FL), whilst brown trout ranged between 32 cm and 60 cm FL and redfin perch ranged between 15 cm and 39 cm FL.

Overall, the greatest number of individuals (15 in total) were sampled from gill nets deployed within Cascade Bay (**Table 5-3**). Between zero and five individuals were sampled from all other locations (noting that the data have not been standardised according to relative sampling effort). Similar sampling effort in terms of the number of gill nets was used at Plain Creek Bay and the relative catch abundance was much lower. Rainbow trout were the most ubiquitous species across the reservoir and were caught at five out of six locations sampled (none were caught at Honeysuckle Bay) (**Table 5-3**). Brown trout were caught only at the Talbingo spillway/proposed barge ramp, dam wall, Cascade Bay and Middle Arm. Redfin perch were caught only at Cascade Bay and the Dam Wall. Cascade Bay was the only location where all three species were caught, whereas no individuals were caught at Reference location 2, which is a deep inlet where Glendower Creek drains into the reservoir. This may partly be due to the reduced sampling effort at this location and because the nets were set in deeper water.

One individual redfin perch presented with a skin lesion above the eye and operculum during the survey. This was not observed in any other individuals of redfin perch, trout and goldfish caught in the reservoir, and is unlikely to be cause for concern.

Table 5-3 Summary of catch data for gill net deployments undertaken in Talbingo Reservoir in September 2018.

Common Name	Scientific Name	Spillway	Dam Wall	Plain Ck Bay	Cascade Bay	Middle Arm	Honeysuckle Bay	Glendowner Ck	**Total**
Non-native Species									
Redfin perch	*Perca fluviatilis*	0	1	0	5	0	0	0	**6**
Rainbow trout	*Oncorhynchus mykiss*	1	0	3	1	2	0	2	**9**
Brown trout	*Salmo trutta*	4	1	0	9	2	0	0	**16**

5.2.2.2 Tantangara Reservoir

A total of 89 fish, including rainbow trout and brown trout were caught in gill nets over the two-day gill netting survey within Tantangara Reservoir in October 2018. Brown trout were the most abundant species recorded across the survey (77 individuals caught in total), followed by rainbow trout (12 individuals). The size of rainbow trout captured ranged between 28 cm and 35 cm FL, whilst brown trout ranged between 19 cm and 65 cm FL.

Overall, the greatest number of individuals (40 in total) were caught within Reference location 1 (near where the Murrumbidgee River and Nungar Creek enter Tantangara Reservoir). This compared with 36 individuals sampled at Tantangara South (near the proposed intake structure) and 13 individuals from Tantangara Mid (near the proposed placement area) (**Table 5-4**). Rainbow trout were most abundant within Tantangara Mid (with 8 individuals), whilst brown trout were most abundant within Reference location 1 (39 individuals).

Table 5-4 Summary of catch data for gill net deployments undertaken in Tantangara Reservoir in October 2018.

Common Name	Scientific Name	Tantangara South	Tantangara Mid	Murrumbidgee River /Nungar Ck	Total
Non-native Species					
Rainbow trout	*Oncorhynchus mykiss*	3	8	1	**12**
Brown trout	*Salmo trutta*	33	5	39	**77**

5.2.3 Bait Traps

5.2.3.1 Talbingo Reservoir

A single fish was caught in bait traps deployed within Talbingo Reservoir during January 2019 a juvenile redfin perch (FL 5 cm) sampled from Middle Arm near the existing boat ramp within one of the traps set overnight. Numerous individuals (approx. 50) of probably eastern gambusia were observed within the vicinity of the bait traps deployed within Middle Arm south of the existing boat ramp, although none were caught in the bait traps. It is thought that warm surface water temperatures (~ 28 °C) at the time of the survey may have contributed to the low catch rates, as fish may have moved into cooler, deeper waters during daylight hours.

Two small specimens of the common yabby were sampled within the bait traps, with one individual caught at each of Cascade Bay (along the northern shoreline) and Plain Creek Bay (along the eastern shoreline) in approximately 2 m of water.

5.2.3.2 Tantangara Reservoir

No fish were caught in bait traps deployed within Tantangara Reservoir during the January 2019 survey. As with Talbingo Reservoir, a number of small specimens of common yabby were captured, with five individuals sampled from Tantangara South (near the proposed intake structure) and five from the Tantangara Mid location (within the vicinity of the proposed placement area). The occurrence of common yabby in Tantangara Reservoir possibly represents translocation, as it would not be expected at such elevation (Tarmo Raadik Pers. Comm. June 2019).

5.2.4 Hoop Nets

5.2.4.1 Talbingo Reservoir

One Murray crayfish (berried female) was captured along the northern shoreline of Ravine Bay at a depth of 8.4 m during the survey of Talbingo Reservoir (**Figure 5-3**). This crayfish measured 105 mm OCL and in Stage 3 of sexual maturity. Baits with marks suggestive of feeding were retrieved from nets at a number of locations, including:

> Plain Creek Bay (depth: 9.6 m);
> Cascade Bay (depth: 7.7 m); and
> Honeysuckle Bay (depth 7.5 m, 9.1 m, 9.3 m and 9.6 m).

The findings of surveys for Murray crayfish in Talbingo Reservoir undertaken by Aquasave are described in (**Section 4.1.9**)

Figure 5-3 Female Murray crayfish sampled within Talbingo Reservoir sampled in October 2018.

5.2.4.2 Tantangara Reservoir

No mobile macroinvertebrates were captured in the 92 hoop nets deployed during the survey undertaken in October 2018 and no chewed baits were observed during the sampling. According to Lintermans (2019), Murray crayfish are not known to occur within Tantangara Reservoir. Our results support this conclusion.

5.2.5 Watercourses

The results of sampling for fish and crayfish in watercourses are summarised in **Table 5-5**. The key findings from surveys in January 2018 to March 2019 were:

> Brown trout and rainbow trout were caught in each catchment and watercourse and overall were the most abundant species caught. Juvenile and adult brown trout were caught in each watercourse, with juvenile brown trout particularly abundant in Mosquito Creek;

> Redfin perch were caught in the Yarrangobilly River and Wallaces Creek only;

> Murray crayfish were caught in Yarrangobilly River and Wallaces Creek only;

> All *Euastacus* sp. Individuals collected in the Upper Murrumbidgee catchment were likely to be Reik's crayfish (based on confirmed identification of a selection of specimens from various watercourses);

> Common yabbies were caught in the Mid-Murrumbidgee River just downstream of Tantangara Reservoir dam wall.

> Two climbing galaxias were caught in the Yarrangobilly River;

> Mountain galaxias was caught at Site 9a on the Murrumbidgee River (a few hundred metres downstream of the confluence with Tantangara Creek) on each occasion it was visited (January/February 2018, May 2018, December 2018 and March 2019). This species was also caught in Tantangara Creek just upstream of the confluence with the Murrumbidgee River in May 2018 and December 2018 and March 2019 (data combined with that for Site 9a). Specimens collected from May 2018 were retained for detailed morphological examination and were confirmed not to be stocky galaxias (Raadik 2018). These specimens were also sympatric (co-occurring) with rainbow trout and brown trout, while the stocky galaxias is considered unable to occur alongside salmonids. Specimens were not caught further upstream (Site 9b) or downstream (Site 9c) on the Murrumbidgee River, further upstream in Tantangara Creek (Sites 8, TC1, TC2, TCA1/2) or in any other watercourse in the upper Murrumbidgee River Catchment. The watercourse habitat in this area, and particularly in the Murrumbidgee River, included a relatively large channel width (approx. 10 m) with a well-defined riffle pool sequence. Mountain galaxias

was found amongst cobbles and boulder substrata. Aquatic habitat further upstream in Tantangara Creek and in other watercourses in the upper Murrumbidgee River Catchment generally consisted of a narrower channel (< 5 m) with a greater proportion of pebble-gravel substrata than cobble-boulder substrata. It is possible that differences in habitat explain the apparent distribution of this species, which probably shelters from predation amongst the larger and more abundant interstices provided by cobble and boulder substratum. Mountain galaxias was caught in the Murrumbidgee River approximately 1 km downstream of Tantangara Dam in Jan/Feb 2018 and May 2018. These specimens were found in structural habitat including timber debris and rock, differing from habitat where mountain galaxias in the Upper Murrumbidgee River were found (amongst cobbles in the riffle zone).

Raadik (2018) tentatively identified these specimens as mountain galaxias, noting a degree of morphological difference between these specimens and published keys of mountain galaxias and between the specimens collected from the Upper Murrumbidgee River Catchment and those collected from the Mid Murrumbidgee River Catchment. Raadik (2018) suggested that the level of morphological difference observed in these galaxiids could represent previously unrecognised levels of divergence in mountain galaxias or the presence of additional, but unidentified, species in the mountain galaxias species complex. Raadik (2018) noted the level of morphological distinction between specimens from the Upper and Mid Murrumbidgee River was relatively great given the relatively minimal degree of geographic separation (approximately 20 km watercourse length). Although Tantangara dam wall is a barrier to movement between these populations, isolation due to the dam is likely to be too short a timeframe to explain the difference in morphology observed (Raadik, 2018).

Whether these two populations in the Upper and Mid Murrumbidgee River are mountain galaxias as tentatively identified, or alternatively, represent either one or two separate undescribed species within the mountain galaxias cryptic species complex, has important implications for the consideration of impacts. If these populations are distinct from mountain galaxias and represent two separate species, consequences of the Project for either population are much greater (i.e. the potential extinction) than loss of a local population. Alternatively, the populations both may be mountain galaxias and the observed morphological differences represent greater intra-species variation than observed previously. Taking a precautionary approach, the impact assessment assumes that there are of two undescribed and potentially narrow-range species; one in the Upper Murrumbidgee River and one in the Mid Murrumbidgee River.

It is conceivable that the several previous identifications of mountain galaxias lower downstream in the Murrumbidgee River (e.g. Gilligan, 2005; NSW DPI, 2017b; Lintermans, 2019) represent observations of this potentially undescribed species in the Mid Murrumbidgee River. Aside from stocky galaxias, there no known recent records of galaxiids from the upper Murrumbidgee River Catchment. There is a historic (1975) record of mountain galaxias from Gurrangorambla Creek (a tributary of Mosquito Creek) (ALA, 2019) that could represent an observation of any potentially undescribed species in the Upper Murrumbidgee River. Any galaxiids present in the Upper Murrumbidgee River Catchment (with the exception of stocky galaxias) are able to co-exist with predatory salmonids (albeit likely in reduced abundance). Galaxiids present in the Mid Murrumbidgee River also co-occurred with salmonids. While this indicates they are somewhat tolerant of the impact of predation from salmonids, it may result in increased susceptibility to impacts associated with predation and / or competition from other species. This is considered in the impact assessment.

> The disconnected pools associated with Gooandra Creek, Tantangara Creek and Nungar Creek appear to provide limited habitat for aquatic biota. The only aquatic fauna identified from all the pools visited were *Euastacus* sp. (likely Reik's Crayfish) in one of the pools near Nungar Creek in December 2018. These pools also appear to be ephemeral, with several pools near Gooandra Creek and Tantangara Creek that contained water in December 2018 were dry in March 2018 (Nungar Creek pools were not visited in March 2019). These pools provide important breeding habitat for frogs, with tadpoles observed in the majority of pools.

Table 5-5 Results of fish and crayfish surveys in watercourses

Watercourse	Site	Method	Unidentified juvenile galaxiid	*Galaxias olidus**	Brown trout	Rainbow trout	Redfin perch	Murray crayfish	Euastacus sp.**	Common yabby	Climbing galaxias
Native Status:			Native	Native	Non-native	Non-native	Non-native	Threatened - Native	Native	Native***	Native***
Yarrangobilly River Catchment											
Yarrangobilly River	1a	BE (480 s)	4		33	1					
	1a	BE (480 s)			12						
	YR1	BE (1200 s)			7	2	9				
		FN (2)									
		BT (8)									
		HN (2)									
	YR2	BE (1200 s)			7	2	14	1			
		FN (2)									
		BT (8)									
		HN (2)									
	TR-18-230 (4)	BE (1873 s)			1	1	1				
	TR-18-232 (5)	BE (1825 s)			1	1					
	TR-18-233 (6)	BE (1880 s)			1	1					2
Wallace's Creek	2a	BE (480 s)			42	3	2	4			
	TR-18-231 (7)	BE (1201 s)			1	1		1			
O'Hare's Creek	13	BE (480 s)									
Upper Murrumbidgee River Catchment											
Upper Murrumbidgee River	9a	BE (480 s)		2	64						
	9a	BE (1200 s)		4							
	9a	BE (600 s)		6	7				3		
	9b	BE (480 s)			230						
		BE (1200 s)			8	2					
		FN (3)			1	1					
		BT (8)									
		HN (2)									
	9c	BE (480 s)							1		
	MR1	BE (1200 s)			4	2			3		
		FN (3)									
		BT (8)									
		HN (2)									
	TR-18-226 (2)	BE (3288 s)		22	1	1			4		
Tantangara Creek	8	BE (480 s)			29	2					
	TC Pool1	EF									

Watercourse	Site	Method	Unidentified juvenile galaxiid	*Galaxias olidus**	Brown trout	Rainbow trout	Redfin perch	Murray crayfish	Euastacus sp.**	Common yabby	Climbing galaxias
Native Status:			Native	Native	Non-native	Non-native	Non-native	Threatened - Native	Native	Native***	Native***
		HN (2)									
	TC1	BE (1200 s)			1	1			2		
		FN (4)									
		BT (8)									
	TC1	BE (1200 s)			6				2		
	TC2	BE (1200 s)									
		FN (3)									
		BT (8)									
	TC2	BE (1200 s)			2						
	TCA1/2	BE (1200 s)			13				4		
		FN (2)			1						
		BT (8)									
	TR-18-229 (3)	BE (280 s)		12	1	1					
Gooandra Creek	5	BE (480 s)			2						
	GC Pool 1	BE (150 s)									
		BT (8)									
		HN (2)									
	GC1	BE (1200 s)			5	3			2		
		FN (2)									
		BT (8)									
	GC1	BE (1200 s)			5	13			2		
	GC2	BE (1200 s)				1					
		FN (2)									
		BT (8)									
	GC2	BE (1200 s)			13	10			2		
Nungar Creek	16	BE (480 s)			31						
	NC Pool 1	EF (150 s)							2		
		BT (4)									
		HN (2)									
	NC Pool 2	EF (150 s)									
		BT (4)									
		HN (2)									
	NC Pool 3	EF (150 s)									
		BT (4)									
		HN (2)									

Watercourse	Site	Method	Unidentified juvenile galaxiid	*Galaxias olidus**	Brown trout	Rainbow trout	Redfin perch	Murray crayfish	Euastacus sp.**	Common yabby	Climbing galaxias
Native Status:			Native	Native	Non-native	Non-native	Non-native	Threatened - Native	Native	Native***	Native***
	NC1	BE (1200 s)			10				4		
		FN (2)									
		BT (8)									
	NC2	BE (1200 s)			17				1		
		FN (2)									
		BT (8)									
Mufflers Creek	6	BE (480 s)			18						
Kelly's Plain Creek	7	BE (480 s)			2	5					
Ghost Gully	15	BE (480 s)			27				4		
Mosquito Creek	MC1	BE (1200 s)			78				11		
Goodradigbee River	26	BE (480 s)			6	1					
Lake Eucumbene Catchment											
Eucumbene River	14	BE (480 s)			23						
	ER1	BE (1200 s)				4			6		
	ER2	BE (1200 s)				10			2		
	ERR3	FN (4)				3					
		BT (8)									
		HN (2)									
Mid Murrumbidgee River Catchment											
Mid-Murrumbidgee River	25	BE (480 s)		8	6	5					
	TR-18-225 (1)	BE (3086 s)		48	1					4	

*Specimens caught in the Upper and Mid Murrumbidgee River were identified tentatively as *Galaxias olidus* (Raadik, 2018). It is unclear if the level of morphological differences identified in these specimens represents previously unrecorded levels of diversity within this species or potentially undescribed species (Raadik, 2018).

**All individuals likely to be Reik's crayfish, a selection of larger specimens from Murrumbidgee River, Tantangara Creek, Gooandra Creek and Mosquito Creek were confirmed as Reik's crayfish following detailed morphological analysis.

***Native to Australia, but not these catchments.

5.2.6 eDNA

5.2.6.1 General Findings

The multi-species assay project detected up to nine native fish species, ten non-native fish species and six decapod crustacean species across the study area (EnviroDNA, 2019a) **(Table 5-6)**. DNA from similar numbers of species of native and non-native fish species were detected, but non-native fish were more widespread across the study area and, presumably (based on relative DNA abundances), higher in abundance and biomass, which is consistent with the results of the traditional sampling (**Section 5.2**). Native fish species were detected at relatively few sites, with apparently localised distributions and generally low relative DNA abundances.

5.2.6.2 Non-native Species

Redfin perch were detected at every site within Talbingo Reservoir and Jounama Pondage, and nearby sites upstream of Talbingo Reservoir within the Yarrangobilly River. No redfin perch were identified within Tantangara Reservoir, its associated tributaries or any of the other sites sampled.

Salmonids were the most prevalent group of fish detected, being found in every waterway and at nearly every site sampled (92% of 50 sites). The fish assay detected all three trout species (brown, rainbow and brook) known to be stocked within the study area. Consistent with the field surveys and DPI fish stocking records, brown trout and rainbow trout were widely distributed throughout the study area, whereas brook trout were detected only at Three Mile Creek, a tributary of Lake Eucumbene.

Several other common non-native fish species were detected within the study area. Wild goldfish and eastern gambusia had a mostly overlapping distribution; they were identified at many sites within Talbingo Reservoir and Jounama Pondage and in the Murrumbidgee River at Cooma, downstream of Tantangara Reservoir. Common carp were also detected in the Murrumbidgee River at Cooma. Trace amounts of carp DNA (approx. 1% total site reads) were detected at one site within Talbingo Reservoir, at the entrance of Middle Creek. It appears more likely that this DNA represents transport of DNA by human or animal vectors, rather than the presence of live fish within the reservoir. If a population of carp were present, then it would be expected that carp DNA would have been detected at more sites and in greater relative abundance. By contrast, DNA from redfin perch, eastern gambusia and wild goldfish (substantial populations of which are present in the reservoir) was more widespread (detected in 9 to 12 of the 12 sites sampled) and relatively abundant at individual sites (up to 91% for redfin perch, 39 % for eastern gambusia and 76 % for wild goldfish). Carp are highly fecund and, once introduced to suitable habitat (such as Talbingo Reservoir), would be expected to rapidly form large and easily detectable populations.

DNA from other non-native fish was also detected. DNA corresponding to three species of Order: Cypriniformes (carps, goldfish and minnows in Family Cyprinidae) and several families of loaches (Cypriniforme OTU1, OTU2 and OTU3) were also detected across the study area. No Cypriniformes are native to Australia. DNA from two of these (Cypriniforme OTU1 and OTU3) was detected in Talbingo Reservoir at a low rate of detection and at a low relative abundance comparable to or lower than that for carp. Thus, the data more likely represent transfer of DNA from outside the study area by animal or human vectors, rather than live fish within the reservoir. DNA from Cypriniforme OTU2 was detected in Talbingo Reservoir and Jounama Pondage at a low rate of detection (1 of 12 sites in Talbingo Reservoir and 1 of 4 sites in Jounama Pondage) and at low relative abundance (< 1 %). It was also detected at low (1 %) relative abundance at one site on the upper Murrumbidgee River and at slightly greater (5 %) relative abundance at one site on Gooandra Creek, both of which are upstream of Tantangara Reservoir. Although detected in slightly greater relative abundance in Gooandra Creek, this is still relatively low, and, given the low rate of detection across the upper Murrumbidgee Catchment (2 out of 13 sites), it is more likely these detections represent transfer of DNA from outside the study area by animal or human vectors, rather than resident live fish. In addition, no cypriniformes, including carp, were detected in any of the known fish surveys undertaken in Talbingo Reservoir and watercourses in the Upper Murrumbidgee Catchment previously and during the current study (**Section 5.2**). In particular, no cypriniformes were detected in Gooandra Creek despite the extensive fish surveys undertaken using traditional methods.

5.2.6.3 Native Species

Neither trout cod nor Macquarie perch were detected by the eDNA fish assay. Murray cod and golden perch DNA was detected at low relative abundance in Jounama Pondage where they are known to have been stocked by NSW DPI.

DNA material corresponding to two species in the mountain galaxias species complex was identified within the study area. These results must be interpreted with caution given the close relationships of species within the *Galaxias* genus and the lack of tissue samples from local populations that are required to identify specific haplotypes. A haplotype that is common to several species in the mountain galaxias complex was detected at Talbingo Reservoir, and based on the known distributions of species (Raadik, 2014), it is probable that the DNA is from mountain galaxias. A haplotype corresponding to stocky galaxias was detected within Tantangara Creek, Tantangara Reservoir, Kelly's Plain Creek and the Murrumbidgee River upstream and downstream of Tantangara Reservoir. These detections were located between approximately 10 km and 100 km downstream of where stocky galaxias are known to occur. Based on the locations of the detections, compared with the results of electrofishing, these detections most likely correspond to the galaxiids caught during electrofishing surveys in the Upper and Mid-Murrumbidgee catchments which were confirmed by Raadik (2018) not to be stocky galaxias and were tentatively identified as mountain galaxias (**Section 5.2.5**)

DNA from climbing galaxias was detected in Gang Gang Creek and Wallaces Creek, which is consistent with the electrofishing sampling that detected this species at Wallaces Creek and the known distribution of this species with the Eucumbene catchment.

DNA from two-spined blackfish, flathead gudgeon and Australian smelt was detected at low abundance at few sites. The geographical range of each of these species is known to include the study area (Allen et al., 2002; Lintermans, 2007). In particular, the Australian smelt was detected at 1 % relative DNA abundance at one site in Talbingo Reservoir. Similarly, shortfinned eel was detected at low relative DNA abundance at one site in each of Tantangara Reservoir and Talbingo Reservoir. This species is not considered native to the Murray-Darling basin, but there are occasional reports of it being present in the Upper Murrumbidgee Catchment (Lintermans, 2007). Most occurrences are thought to be the result of translocations by anglers, but some may be due to rare natural dispersal events (Lintermans, 2002; Lintermans, 2007). Low level detections of DNA from golden perch and Murray cod were also recorded in Jounama Pondage, where these species have been stocked. Golden perch DNA was detected in low relative abundance (<1 %) in Talbingo Reservoir.

DNA from potentially three spiny crayfish species was identified within the study area. DNA from Reik's crayfish was detected at sites within the Upper Murrumbidgee River and Lake Eucumbene catchments, which is consistent with other sampling undertaken for this study (**Section 5.2**). DNA from Murray crayfish was detected in the Yarrangobilly River and Wallaces Creek with a low level detection also recorded in Talbingo Reservoir at the inflow of Yarrangobilly River. *Euastacus* DNA that appeared to be distinct from the Murray crayfish and Reik's crayfish was detected in Wallaces Creek. Only three species of *Euastacus* are known to occur within the study area (Morgan 1997; Shull et al., 2005) and it is possible that this DNA corresponds to alpine spiny crayfish, however without reference DNA in the database and the close similarity with Reik's crayfish the presence of a third spiny crayfish could not be confirmed.

The common yabby (*Cherax destructor*) was detected in Talbingo Reservoir, Tantangara Reservoir, Jounama Pondage and several creek/river sites, which was consistent with physical sampling that recorded yabbies in Talbingo and Tantangara reservoirs (**Section 5.2**). DNA from freshwater glass shrimp (*Paratya australiensis*) was found in Talbingo Reservoir, Jounama Pondage, Middle Creek and the Murrumbidgee River at Cooma. DNA from freshwater shrimp (Family: Palaemonidae) was also detected in the Murrumbidgee River at Cooma.

The results of EnviroDNA (2019b) are summarised in (**Table 5-6**). Specifically:

> DNA from redfin perch was detected in the Lower Murrumbidgee River downstream from just upstream of Angle Crossing Road (**Figure 5-4**). Redfin perch DNA was also detected in Khancoban Reservoir, Swampy Plain Creek and the upper Tumut River downstream of T2 Dam and Tumut Pond, all locations where it was previously considered present. Redfin perch DNA was not detected in Lake Eucumbene, Lake Jindabyne, Tumut Pond, T2 Dam, M2 Dam, Bogong Creek, Geehi Reservoir, Geehi River and the Mowamba River Weirpool;

> DNA from eastern gambusia was detected at each site in the Mid-Murrumbidgee River in one of 25 sites in Lake Eucumbene and at one of 21 sites in Lake Jindabyne (**Figure 5-5**). It was absent in all other catchments. Based on the number of samples at each site that contained eastern gambusia DNA, the detection in Lake Eucumbene (3 of 12 samples at one site) and in Lake Jindabyne (2 of 12 samples at one site) were considered a 'weak level positive' and 'equivocal' detections of live individuals, respectively (EnviroDNA, 2019b). Given the localised detection in each lake (i.e. at one site only) and overall low rate of detection (2 out of a total of 84 samples in Lake Jindabyne and 3 out of 99 samples in Lake Eucumbene) it is possible that these may represent cross contamination (the site in Lake Jindabyne was located near a boat ramp). If live fish are present, these results suggest a low abundance and localised population.

> DNA from Macquarie perch was detected in the Mid-Murrumbidgee River, but not in the Lower-Murrumbidgee River (the potential presence of DNA from this species was only assessed in these two catchments) (**Figure 5-6**); and

> DNA from climbing galaxias was detected in the Eucumbene River upstream of Lake Eucumbene and Lake Jindabyne (where it is considered endemic) and also Geehi Reservoir where it has been detected previously (**Section 4.3.4**) (**Figure 5-7**). It was absent from all other catchments where it was assessed.

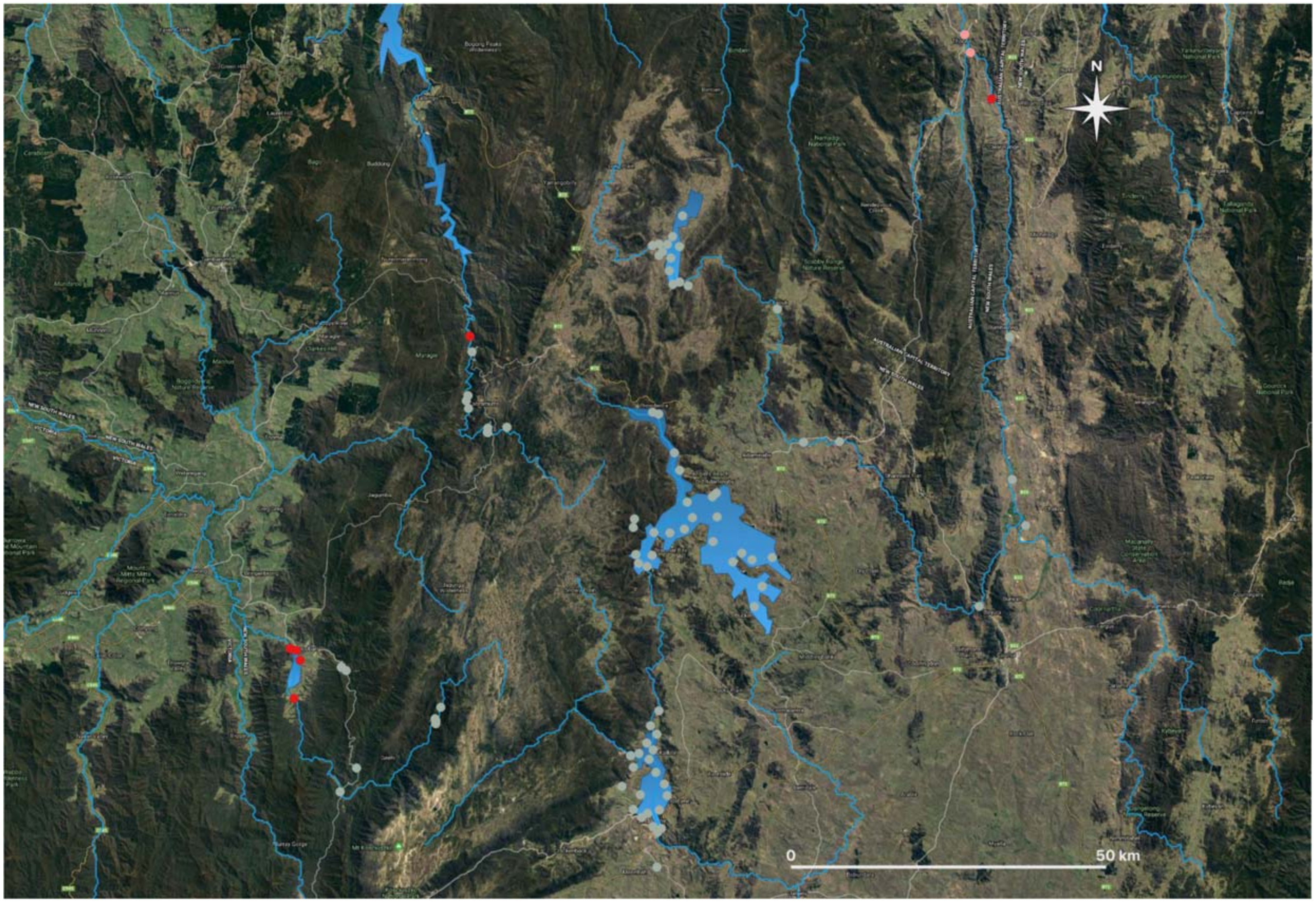


Figure 5-4 Site locations and detections of redfin perch DNA from March 2019 (EnviroDNA, 2019b). Red circles indicate positive results, closed grey circles indicate negative results, and closed pink circles indicate equivocal results

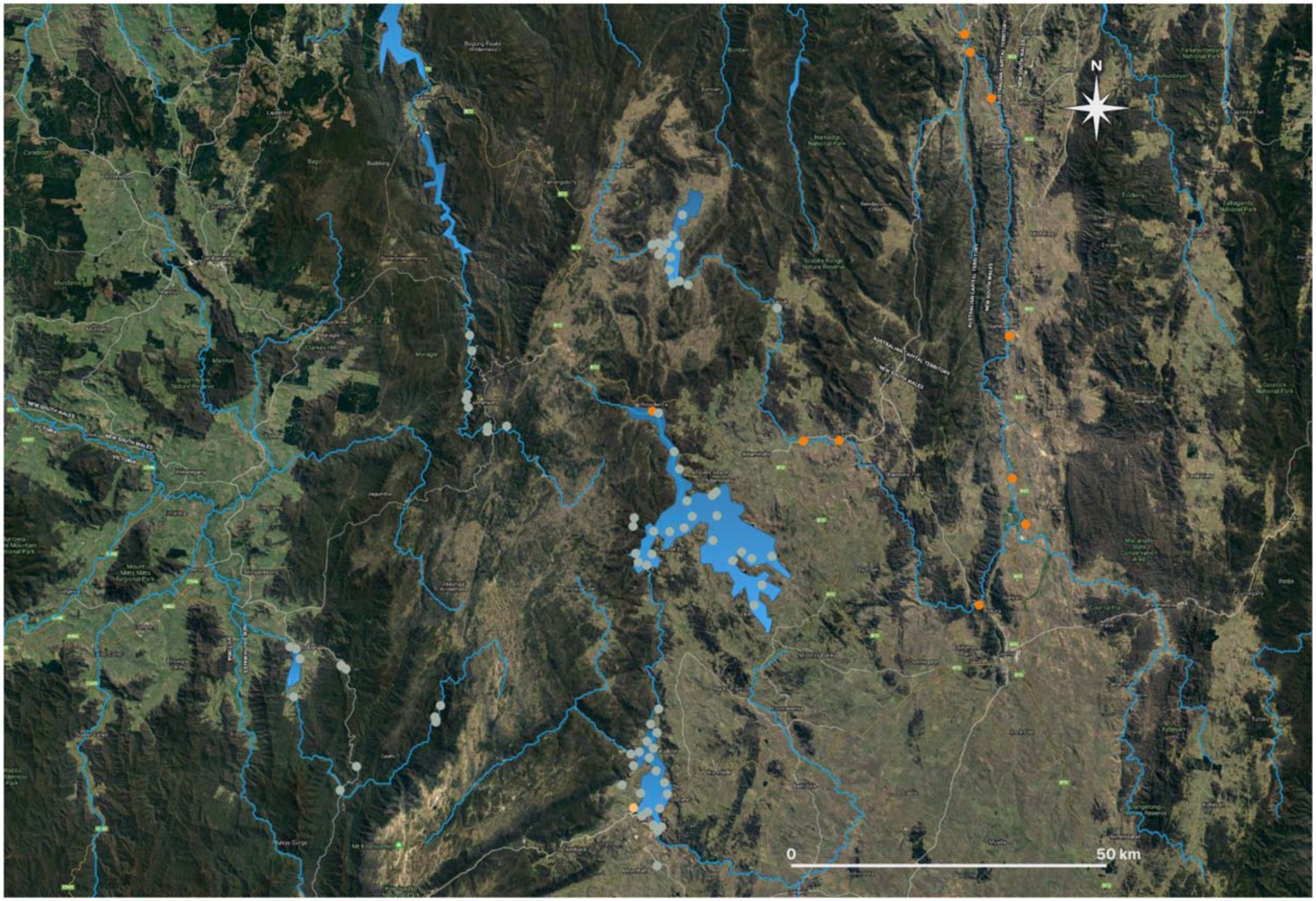


Figure 5-5 Site locations and detections of eastern gambusia DNA from March 2019 (EnviroDNA, 2019b). Orange circles indicate positive results, closed grey circles indicate negative results, and yellow circles indicate equivocal results

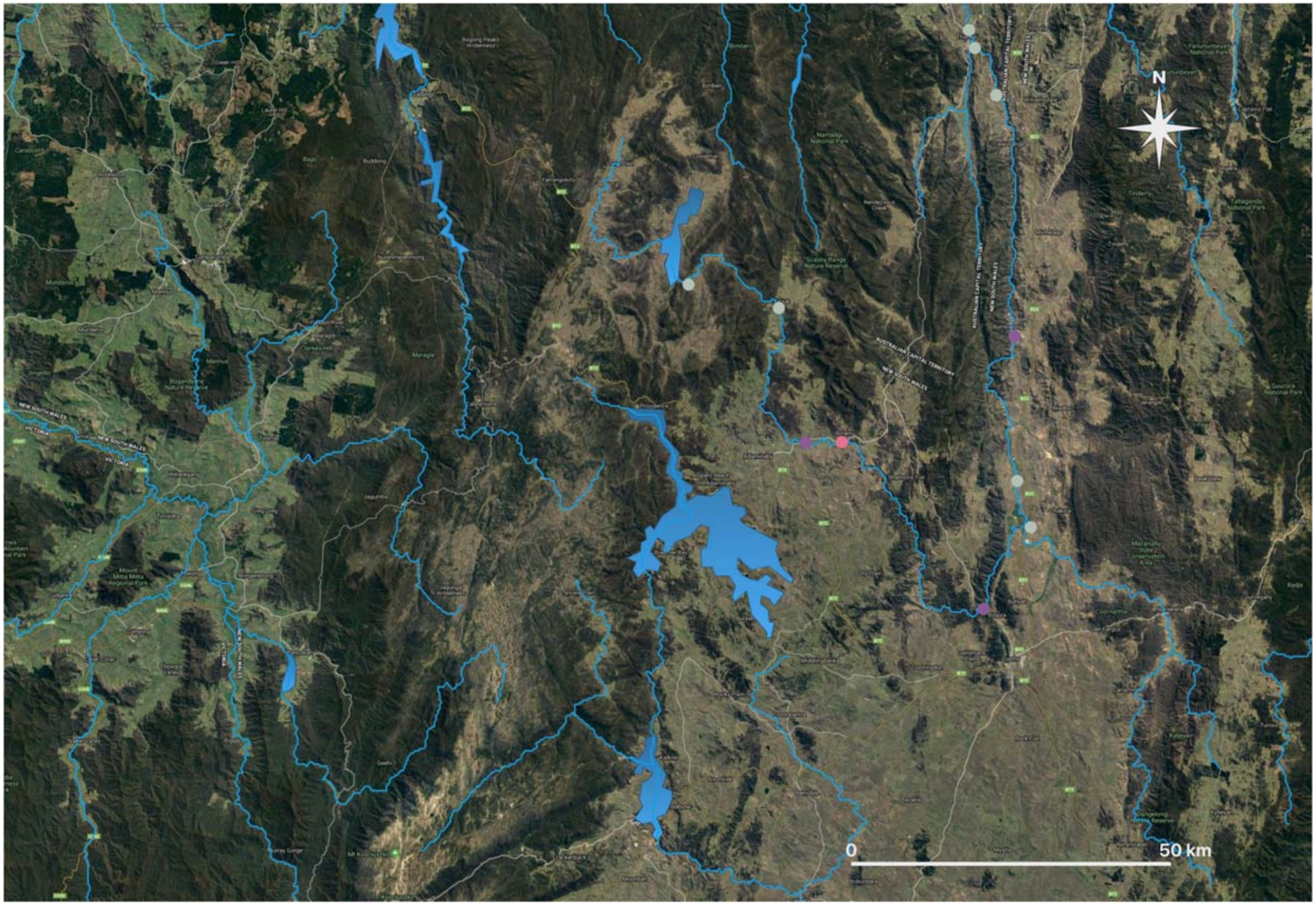


Figure 5-6 Site locations and detections of Macquarie perch DNA from March 2019 (EnviroDNA, 2019b). Purple circles indicate positive results, grey indicate negative results, and pink circles indicate equivocal results

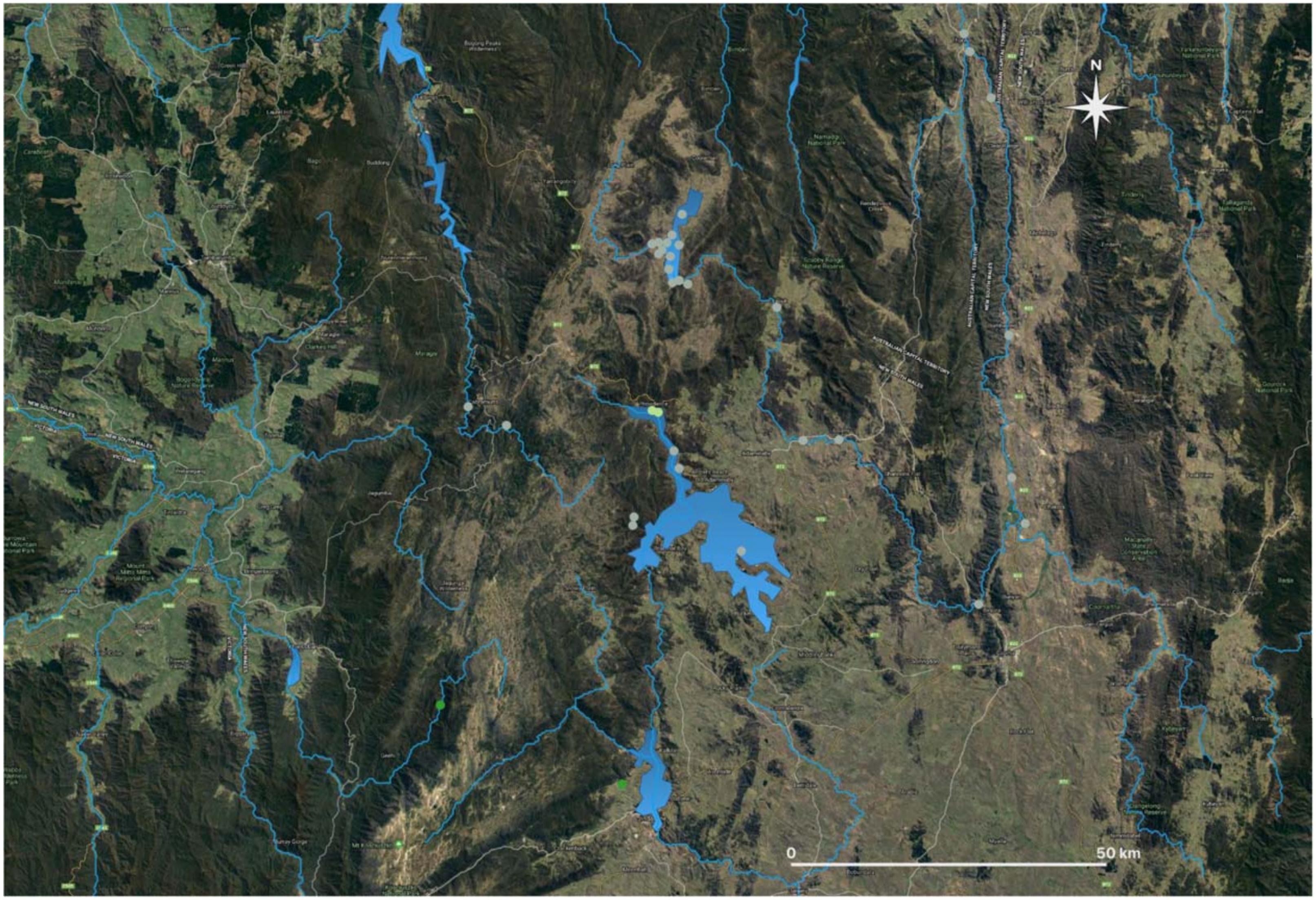


Figure 5-7 Site locations and detections of climbing galaxias DNA from March 2019 (EnviroDNA 2019b). Dark green circles indicate positive results, closed grey circles indicate negative results, and light green circles indicate equivocal results.

Table 5-6 Summary of eDNA surveys results. For (a) EnviroDNA (2019a) and (b) EnviroDNA (2019b). DNA indicates DNA was detected and Neg. indicates DNA was not detected (EnviroDNA 2019b only). For EnviroDNA (2019a), DNA (Low) indicates DNA was detected in relatively low abundance (≤ 1 % relative abundance). In isolation DNA detected in low abundance provides low confidence of the presence of live individuals, and could represent field or laboratory contamination. ns = catchment not included in sampling program. OTU: operational taxonomic unit, used to classify groups of related individuals.

Scientific Name		Common Name	Tumut River Catchment					Murrumbidgee River Catchment						Snowy River Catchment			Murray River Catchment		
			Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Tantangara Reservoir		Upper Murrumbidgee Catchment	Mid-Murrumbidgee Catchment		Lower-Murrumbidgee Catchment	Lake Eucumbene Catchment		Lake Jindabyne Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi Reservoir and M2 Reservoir Catchments
Reference:			a	b	b	a	a	a	b	a	a	b	b	a	b	b	ns	b	b
Threatened Species																			
Percichthyidae	Macquaria australasica	Macquarie perch										DNA	Neg.						
	Maccullochella peelii	Murray cod					DNA (Low)												
Parastacidae	Euastacus armatus	Murray crayfish	DNA (Low)			DNA													
Non-listed Threatened Native Species																			
Percichthyidae	Macquaria ambigua	Golden perch	DNA (Low)				DNA (Low)												
	Gadopsis bispinosus	Two-spinned blackfish	DNA			DNA	DNA (Low)												
Galaxiidae	Galaxias sp.	Galaxias haplotype 1*	DNA																
	Galaxias sp.	Galaxias haplotype 2**						DNA		DNA	DNA								
	Galaxias brevipinnis	Climbing galaxias		Neg.	Neg.	DNA			Neg.			Neg.	Neg.	DNA	DNA	DNA			DNA
Retropinnidae	Retropinna semoni	Australian smelt	DNA (Low)																
Eleotridae	Philypnodon grandiceps	Flathead gudgeon	DNA				DNA (Low)							DNA					
Anguillidae	Anguilla australis	Australian shortfin eel	DNA (Low)					DNA (Low)											
Parastacidae	Cherax destructor	Common yabby	DNA				DNA	DNA		DNA	DNA			DNA					

Scientific Name		Common Name	Tumut River Catchment					Murrumbidgee River Catchment						Snowy River Catchment			Murray River Catchment		
			Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Tantangara Reservoir		Upper Murrumbidgee Catchment	Mid-Murrumbidgee Catchment		Lower-Murrumbidgee Catchment	Lake Eucumbene Catchment		Lake Jindabyne Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi Reservoir and M2 Reservoir Catchments
Reference:			a	b	b	a	a	a	b	a	a	b	b	a	b	b	ns	b	b
	Euastacus reiki	Reik's crayfish						DNA		DNA				DNA					
	Euastacus sp.	Unidentified spiny crayfish***				DNA													
Palaemonidae	Palaemonidae	Freshwater prawn									DNA								
Atyidae	Paratya australiensis	Freshwater glass shrimp	DNA				DNA (Low)				DNA								
Non-native Species																			
Percidae	Perca fluviatilis	Redfin perch	DNA	Neg.	DNA	DNA	DNA		Neg.			Neg.	DNA		Neg.	Neg.		DNA	Neg.
Poeciliidae	Gambusia holbrooki	Eastern gambusia	DNA	Neg.	Neg.		DNA		Neg.		DNA	DNA	DNA		DNA	DNA	Neg.	Neg.	Neg.
Cypriniforme	Cypriniforme OTU1	Cypriniforme OTU1	DNA (Low)																
	Cypriniforme OTU2	Cypriniforme OTU2****	DNA (Low)				DNA (Low)			DNA									
	Cypriniforme OTU3	Cypriniforme OTU3	DNA (Low)																
Cyprinidae	Carassius auratus	Wild goldfish	DNA				DNA				DNA								
	Cyprinus carpio	Carp	DNA (Low)								DNA								
Salmonidae	Oncorhynchus mykiss	Rainbow trout	DNA			DNA	DNA	DNA		DNA	DNA			DNA					
	Salmo trutta	Brown trout	DNA			DNA	DNA	DNA		DNA	DNA			DNA					
	Salvelinus fontinalis	Brook trout												DNA					

*Likely to indicate mountain galaxias based on known species distributions

**Haplotype corresponds to stocky galaxias, however, may also be shared with other species within the mountain galaxias species complex. Specimens of galaxiid collected from this location were not identified as stocky galaxias (Raadik, 2018). The relative DNA abundance was greater than 1 % at one site in Tantangara Reservoir. In the Mid Murrumbidgee River Catchment, it was 53 % in the Murrumbidgee River just downstream of Tantangara Dam wall and 1 % at Cooma Weir (EnviroDNA, 2019a).

***Only three species of *Euastacus* are known to occur within the study area (Morgan 1997; Shulle et al., 2005 in EnviroDNA 2019a); haplotype for third species of spiny crayfish unconfirmed Reik's.

****Relative DNA abundance of 5 % in Gooandra Creek and 1 % in Murrumbidgee River upstream of Tantangara Reservoir.

5.3 Benthic Macroinvertebrates

Freshwater benthic macroinvertebrates are small organisms, generally retained on a 0.5 mm sieve, that live in, and on the substratum of creeks, rivers and lakes/reservoirs. They are able to reside on rocks, logs, sediment, debris and aquatic vegetation during all, or some part of their life cycle. Major groups of benthic invertebrates, include crustaceans, molluscs, aquatic worms and aquatic insects. They are widespread and can live on all substratum types that would be found across the study area. Different forms, or life stages of these invertebrates are also able to move around and expand their distribution by either actively swimming or passively drifting between areas to new locations. They are generally found all year round, although peaks in abundance throughout the year would depend on the taxa/species. Transition between life stages occurs in the aquatic environment for many aquatic macroinvertebrates (i.e. egg to larvae to pupa to adult).

Benthic macroinvertebrates are important in aquatic food webs as they form an intermediate link between lower trophic levels such as microalgae and bacteria (on which many feed) and higher level predators such as crayfish and fish, and some also breakdown organic matter such as leaves and detritus. Therefore, they play a critical role in the flow of energy and nutrient cycling within the aquatic environment.

Benthic infauna in lacustrine systems generally include the immature and adult stages of different types of invertebrates, including many flies, aquatic worms (nematodes and oligochaetes), beetles, mayflies, caddisflies, stoneflies, dragonflies, gastropod and bivalve molluscs and crustaceans (freshwater shrimp and cladocerans) among others. These species perform a variety of functions in freshwater food webs by detrital decomposition (van de Bund, et al., 1994; Wallace & Webster, 1996), releasing nutrients into solution (by their feeding activities, excretion, and burrowing into sediments) and are a source of food for aquatic and terrestrial vertebrates (e.g., fishes, turtles and birds). Finally, benthic organisms accelerate nutrient transfer to overlying open waters of lakes (Clarke, et al., 1997) and adjacent riparian zones of streams (e.g. Wallace, et al., 1997).

Benthic macroinvertebrates are also used to monitor the health of aquatic habitats, including impacts associated with impaired water quality. As they can be susceptible to various pressures and stressors such as organic pollutants, toxicants changes to water quality or sediments and their responses to these pressures are able to be monitored quite easily, they are an ideal pathway to monitor aquatic health in a biological context. Orders such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies) are very sensitive to many pollutants in the stream environment and the abundance of these groups in particular, is used as an 'EPT index' of stream health.

5.3.1 Talbingo Reservoir

5.3.1.1 March 2018 Survey

In total, 1,566 individuals from ten taxonomic groups (Family level or higher) were identified from the 24 samples collected from Talbingo Reservoir in March 2018. Oligochaete worms were the most abundant taxon identified, accounting for 81% of all individuals collected from the reservoir. Nematode worms and Chironomidae (non-biting midges) accounted for 13% and 4%, respectively, of all individuals collected. All other taxa accounted for less than 2% of total abundance within the samples. These included bivalve freshwater molluscs, crustaceans (including copepods and ostracods) and various insects (**Table 5-7**). A breakdown of the abundance and taxonomic richness of major taxonomic groups within Talbingo Reservoir is in **Figure 5-8**.

Table 5-7 Relative abundance and percent contribution of taxa recorded during benthic macroinvertebrate sampling in Talbingo Reservoir in March 2018.

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Oligochaeta	Worm	1272.0	81.2
Nematoda	Worm	200.0	12.8
Chironomidae	Insect	66.0	4.2
Corbiculidae	Mollusca	10.0	0.6
Ostracoda	Crustacean	6.0	0.4
Corbiculidae/ Sphaeriidae	Mollusca	5.0	0.3
Ecnomidae	Insecta (Tricoptera)	3.0	0.2
Copepoda	Crustacean	2.0	0.1
Leptophlebiidae	Insect (Ephemeroptera)	1.0	0.1

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Hydropsychidae	Insect (Tricoptera)	1.0	0.1

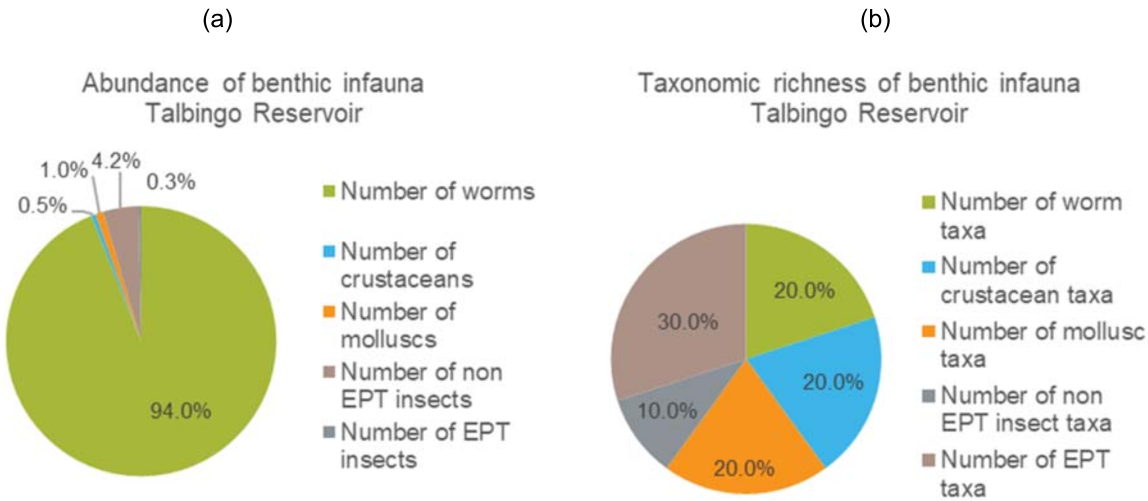


Figure 5-8 (a) Relative abundance and (b) taxonomic richness of major groups of benthic macroinvertebrates sampled in Talbingo Reservoir in March 2018.

In Talbingo Reservoir, mean total abundance was greatest at TALS-SQ-11 at the mouth of Tomneys Plain Creek within Cascade Bay at a water depth range of 24.5 m – 39 m (100.0 individuals ± 54.5) and lowest at TALS-SQ-01, within the middle portion of the reservoir, at a water depth of approximately 53 m (5.0 individuals ± 3.0). Mean taxon richness was also lowest at TAL-SQ-01, (1 taxon recorded) and greatest at TALN-SQ-A (3.5 taxa ± 0.5) at the northern end of Talbingo Reservoir, water depth range between 16 m - 138 m (**Figure 5-9**).

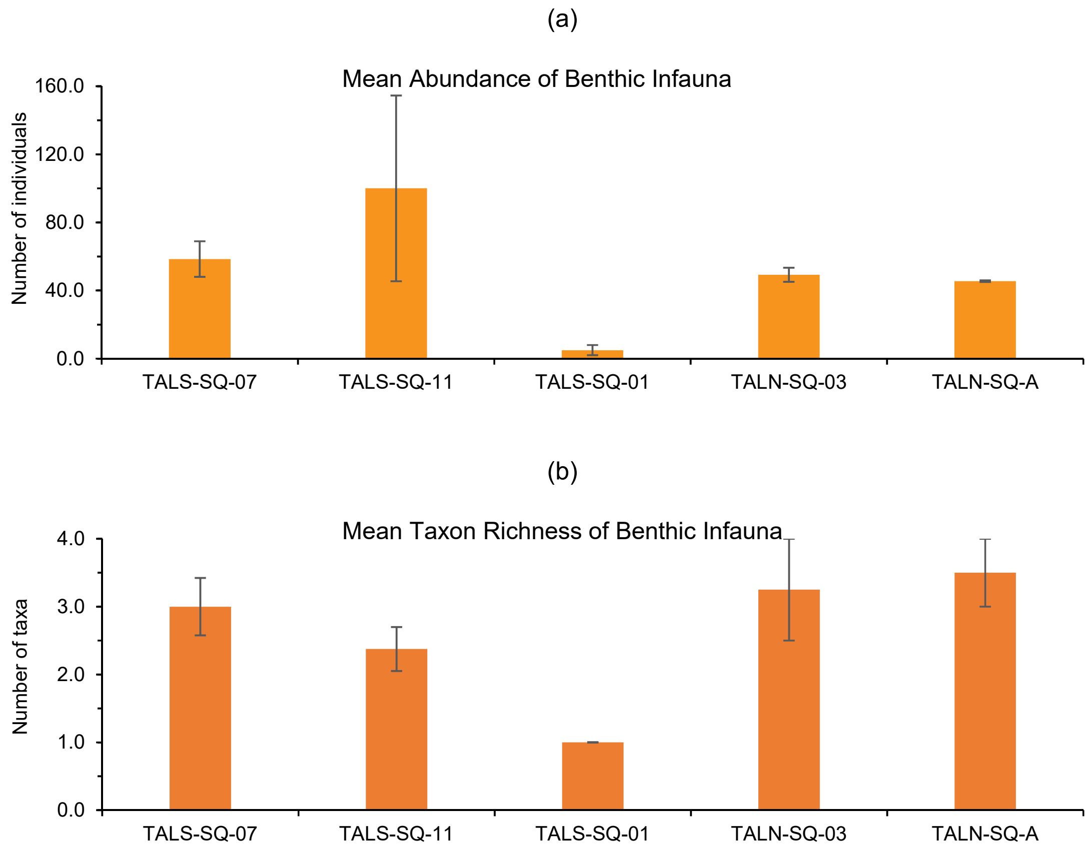


Figure 5-9 a) Mean abundance and b) mean taxon richness of benthic macroinvertebrate assemblages at each location sampled in Talbingo Reservoir in March 2018.

Multivariate statistical analysis indicated that the composition of the benthic macroinvertebrate assemblages at each of the five sampling locations within Talbingo Reservoir sampled within March 2018 varied significantly ($p < 0.05$), with Pairwise Tests indicating that TALS-SQ-01 was significantly different (lower) from most other locations, whilst the other four locations sampled were similar in assemblage composition and abundance. This was also indicated within the nMDS ordination analysis undertaken (**Figure 5-10**).

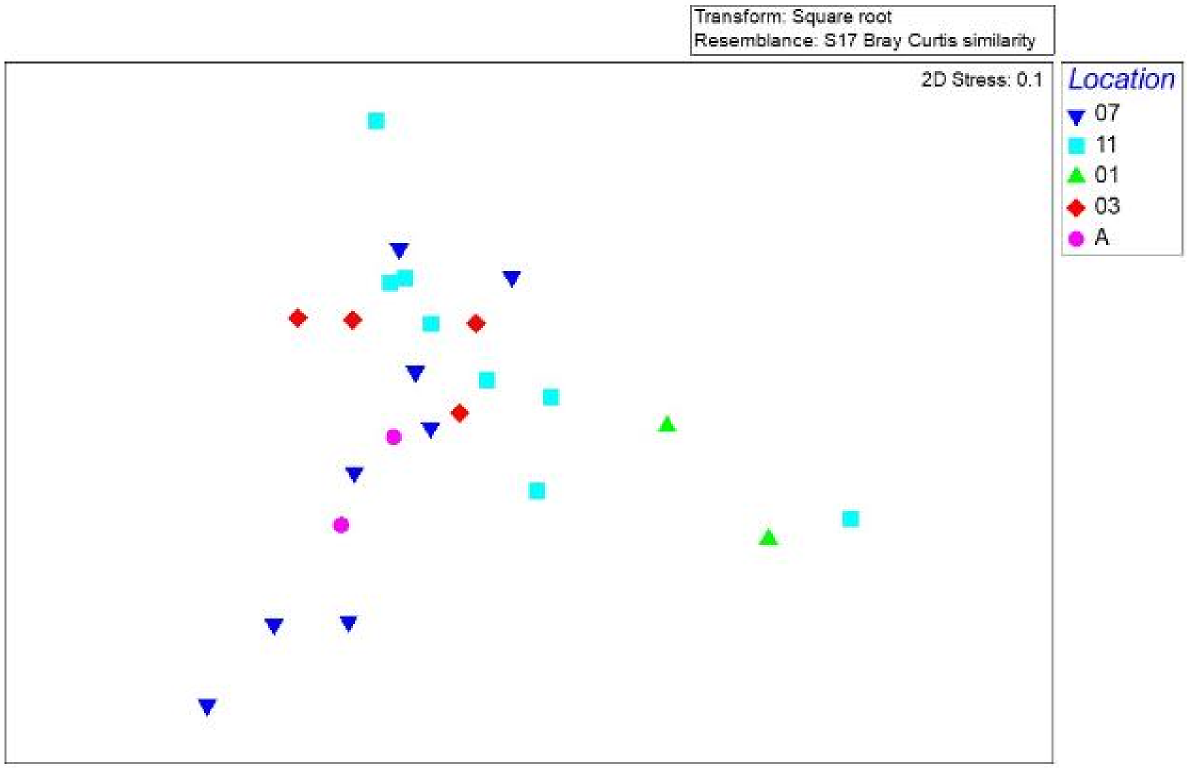


Figure 5-10 Two dimensional non-metric multi-dimensional (nMDS) scaling ordination for the composition of benthic macroinvertebrate assemblages collected from five locations within Talbingo Reservoir in March 2018. Distances between points indicate relative similarities among sampling locations.

These results suggest that although benthic infaunal assemblages may vary at smaller spatial scales within the reservoir, the abundance and composition of assemblages generally tend to be fairly uniform throughout the entire system. For example, benthic infaunal assemblages collected south near the Yarrangobilly River were similar to those sampled near the dam wall further north.

5.3.1.2 January 2019 Survey

A total of 686 individuals from five taxonomic groups (Family level or higher) were identified from the ten samples collected from Talbingo Reservoir in January 2019. Oligochaete worms were the most numerically abundant accounting for 79% of all individuals collected from the reservoir. Chironomidae (non-biting midges) and nematode worms accounted for 13% and 6%, respectively, of all individuals collected. All other taxa collected accounted for just over 2% of total abundance within Talbingo Reservoir. These included bivalve freshwater molluscs and insects (mayflies) (**Table 5-8**). A breakdown of the abundance and taxonomic richness of major taxonomic groups within Talbingo Reservoir is provided in **Figure 5-11**.

Table 5-8 Relative abundance and percent contribution of taxa recorded during benthic macroinvertebrate sampling in Talbingo Reservoir in January 2019.

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Oligochaeta	Worm	544	79.3
Chironomidae	Insect	89	13.0
Nematoda	Worm	38	5.5
Corbiculidae/ Sphaeriidae	Mollusc	14	2.0
Baetidae	Insect (Ephemeroptera)	1	0.1

(a) (b)

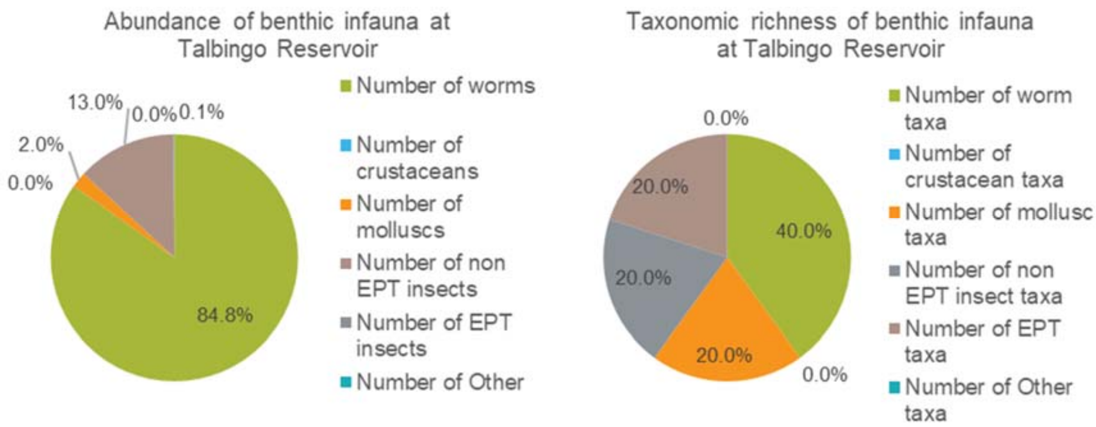


Figure 5-11 (a) Relative abundance and (b) taxonomic richness of major groups of benthic macroinvertebrates sampled in Talbingo Reservoir in January 2019.

In Talbingo Reservoir, mean total abundance was greatest at MA West within Middle Arm at a water depth range of 18.6 m – 21.3 m (83.5 individuals ± 1.5) and lowest at PCB North (29.5 individuals ± 5.5), within the northern portion of Plain Creek Bay (25.6 m – 33.6 m). Mean taxon richness was lowest at PCB South (2.0 ± 1.0 taxa recorded) and greatest at location MA West (4.0 taxa ± 0.0) within the western portion of Middle Arm (**Figure 5-12**).

(a)

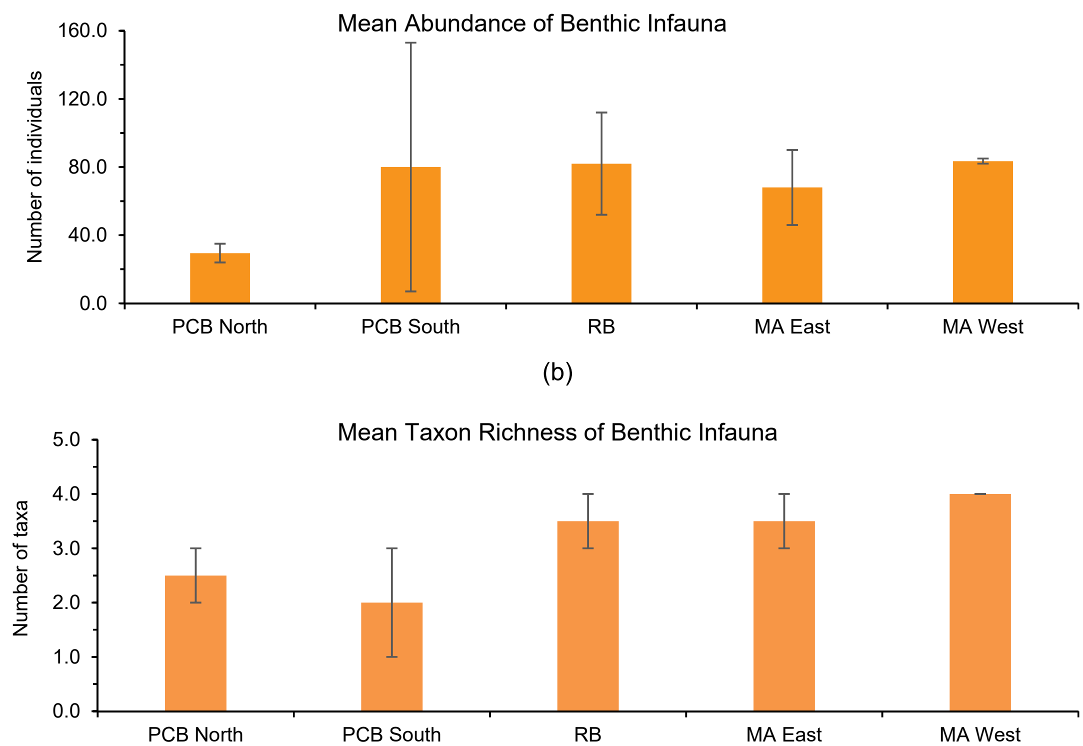


Figure 5-12 a) Mean abundance and b) mean taxon richness of benthic macroinvertebrate assemblages at each location sampled in Talbingo Reservoir in January 2019. PCB = Plain Creek Bay, RB = Ravine Bay, MA = Middle Arm.

Multivariate statistical analysis indicated that the composition of the benthic infaunal assemblages at each of the five sampling locations within Talbingo Reservoir sampled in January 2019 varied significantly ($p < 0.05$), although Pairwise Tests were unable to ascertain where these differences occurred within the data. Due to the presence of a severe outlier for one replicate collected within Plain Creek Bay (PCB S), analyses excluded this outlier to better understand the remaining variability. nMDS ordination analysis revealed that infaunal assemblages within Middle Arm tended to be different from those collected from Plain Creek Bay and Ravine Bay (**Figure 5-13**). Greater variability between samples was evident within Plain Creek Bay and Ravine Bay compared to samples from Ravine Bay (**Figure 5-13**).

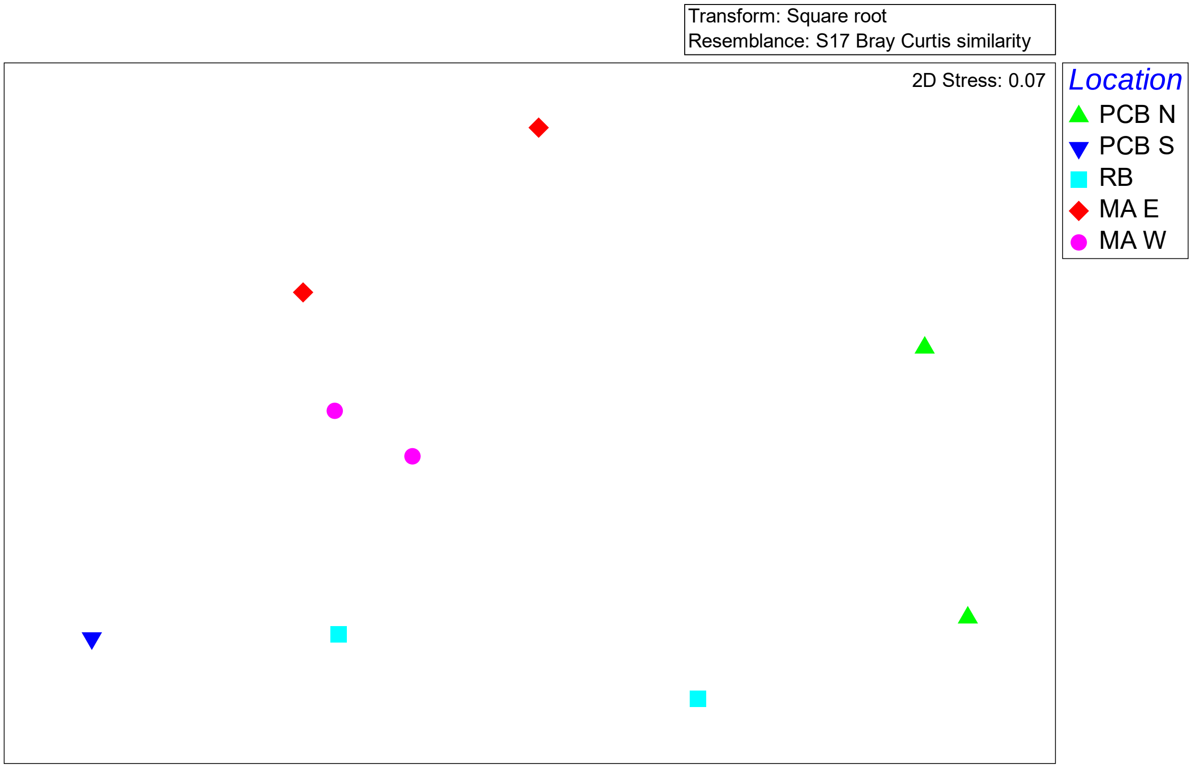


Figure 5-13 Two dimensional non-metric multi-dimensional (nMDS) scaling ordination for the composition of benthic macroinvertebrate assemblages collected from five locations within Talbingo Reservoir in January 2019. Distances between points indicate relative similarities among sampling locations.

5.3.2 Tantangara Reservoir

5.3.2.1 March 2018 Survey

A total of 3,280 individuals from 12 taxonomic groups (Family level or higher) were identified from the 24 samples collected from Tantangara Reservoir in March 2018. Oligochaete worms were the most numerically abundant taxon accounting for 63% of all individuals collected from the reservoir. Chironomidae (non-biting midges) and nematode worms accounted for 20% and 14%, respectively, of all individuals collected. All other taxa accounted for just over 3% of total abundance within Tantangara Reservoir. These included bivalve freshwater molluscs, crustaceans (including, copepods and ostracods) and various insects (**Table 5-9**). A breakdown of the abundance and taxonomic richness of major taxonomic groups within Talbingo Reservoir is in **Figure 5-14**.

Table 5-9 Relative abundance and percent contribution of taxa recorded during benthic macroinvertebrate sampling in Tantangara Reservoir in March 2018.

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Oligochaeta	Worm	2060.0	62.8
Chironomidae	Insect	656.0	20.0
Nematoda	Worm	455.0	13.9
Copepoda	Crustacean	49.0	1.5
Corbiculidae/ Sphaeriidae	Mollusca	28.0	0.9
Corbiculidae	Mollusca	16.0	0.5
Platyhelminthes	Worm	8.0	0.2
Cladocera	Crustacean	3.0	0.1

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Ostracoda	Crustacean	2.0	0.1

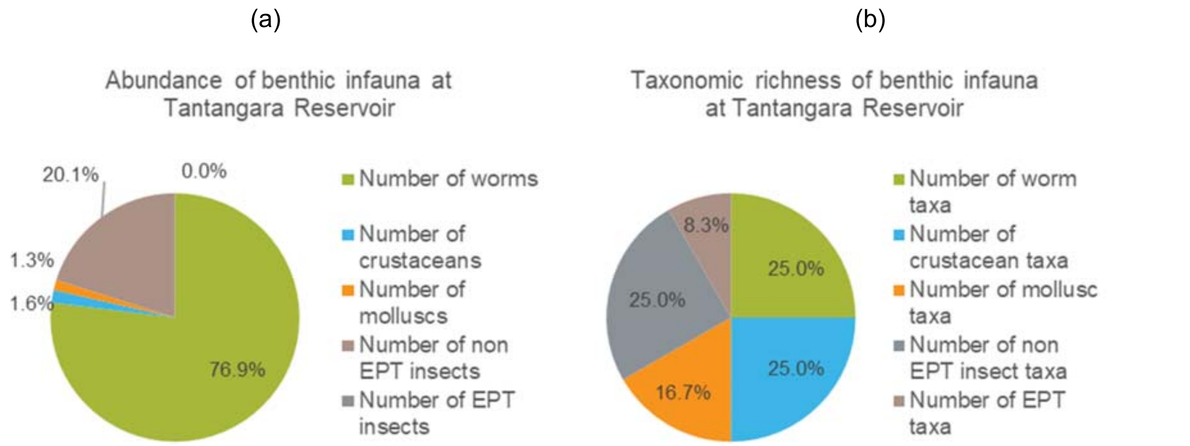


Figure 5-14 (a) Relative abundance and (b) taxonomic richness of major groups of benthic macroinvertebrates sampled in Tantangara Reservoir in March 2018.

Within Tantangara Reservoir mean total abundance was greatest at TANN-SQ-09 at the northern end of the reservoir where the Murrumbidgee River and Nungar Creek flow into the main basin at a water depth range of 5.6 m – 16 m (185.3 individuals ± 36.6) and lowest at TANS-SQ-05 (61.9 individuals ± 14.1), within the southern portion of the reservoir, at a water depth range of 6 – 18.4 m. Mean taxon richness was very similar at all three locations with 3.5 - 3.6 taxa collected at each of the three locations (**Figure 5-15**).

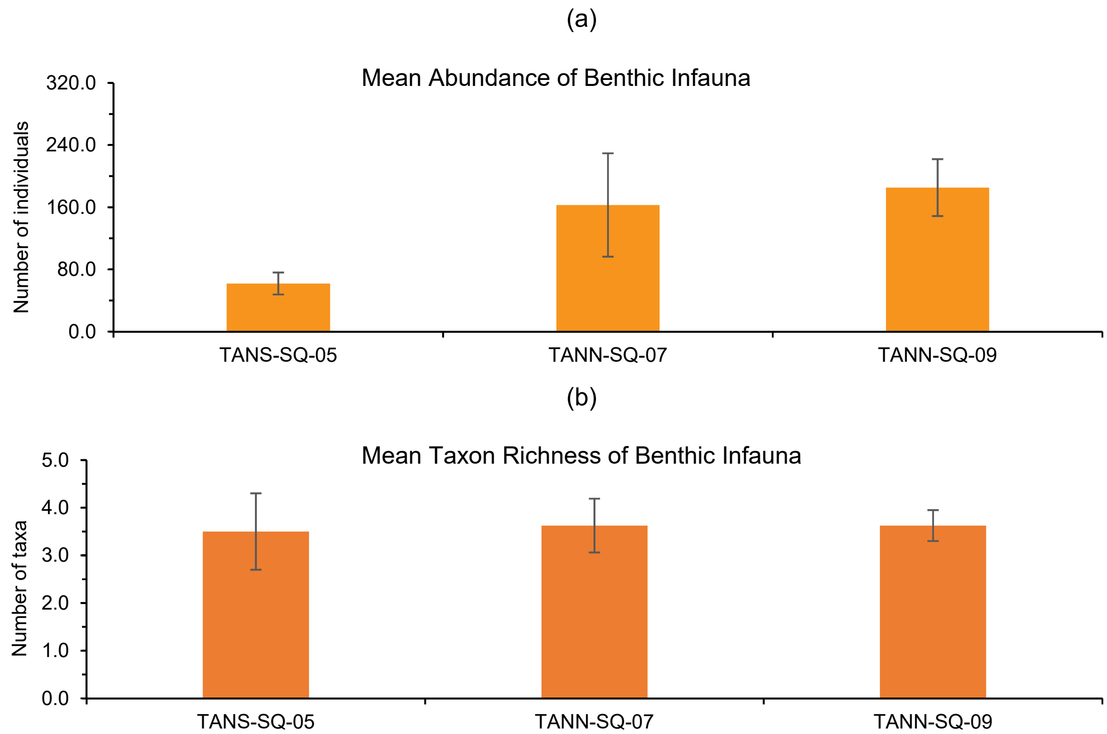


Figure 5-15 a) Mean abundance and b) mean taxon richness of benthic macroinvertebrate assemblages at each location sampled in Tantangara Reservoir in March 2018.

Multivariate statistical analysis indicated that the composition of the benthic macroinvertebrate assemblages at each of the three sampling locations within Tantangara Reservoir did not vary significantly ($p = 0.1714$) (**Figure 5-16**), although significant smaller spatial scale variability did occur among Sites within each location ($p < 0.01$).

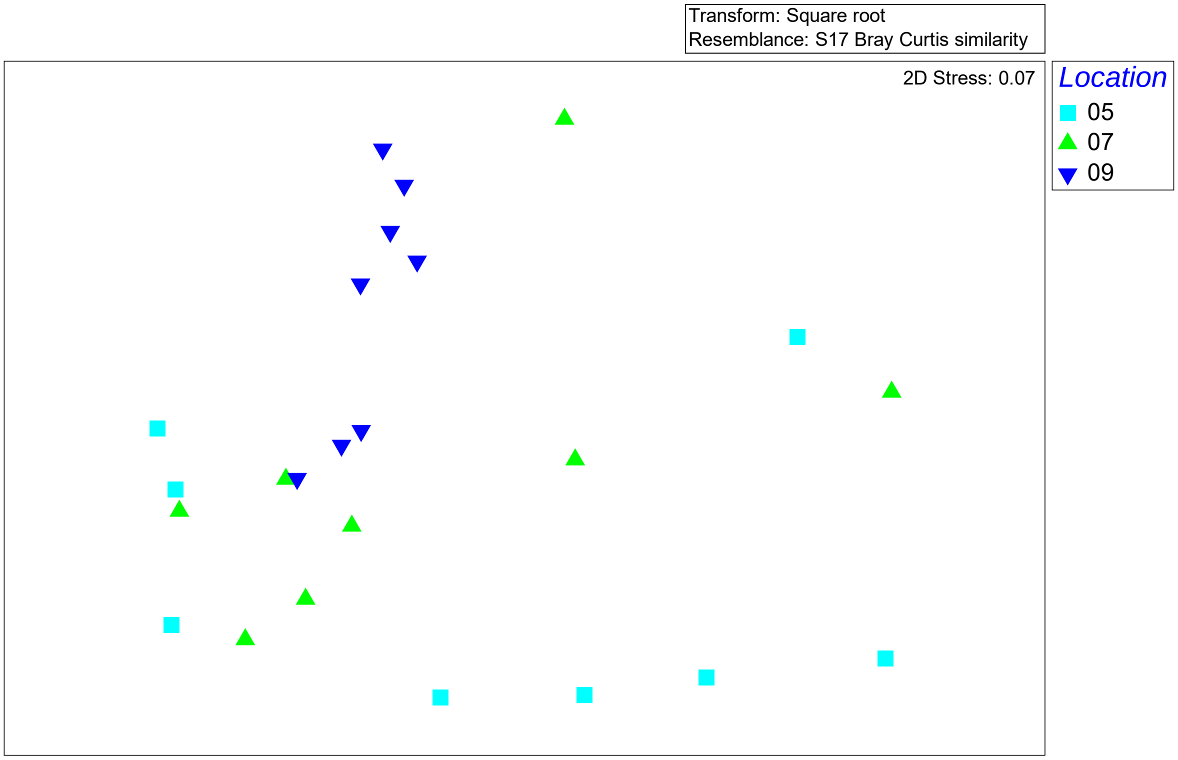


Figure 5-16 Two dimensional non-metric multi-dimensional (nMDS) scaling ordination for the composition of benthic macroinvertebrate assemblages collected from five locations within Tantangara Reservoir in March 2018. Distances between points indicate relative similarities among sampling locations.

Data collected within Tantangara Reservoir suggests that although benthic infaunal assemblages may vary at smaller spatial scales within the reservoir, the abundance and composition of assemblages generally tend to be fairly uniform throughout the entire system. For example, benthic infaunal assemblages collected down south near the Tantangara Reservoir dam wall were relatively similar to those sampled further upstream near the confluence with the Murrumbidgee River and Nungar Creek.

5.3.2.2 January 2019 Survey

A total of 1,488 individuals from seven taxonomic groups (Family level or higher) were identified from the ten samples collected from Tantangara Reservoir in January 2019. Oligochaete worms were the most numerically abundant taxon accounting for 75% of all individuals collected from the reservoir. Chironomidae (non-biting midges) and Nematode worms accounted for 17% and 6%, respectively, of all individuals collected. All other taxa accounted for less than 2% of total abundance within Tantangara Reservoir. These included bivalve freshwater molluscs, hydroids and mites (**Table 5-10**). A breakdown of the abundance and taxonomic richness of major taxonomic groups within Talbingo Reservoir is in **Figure 5-17**.

Table 5-10 Relative abundance and percent contribution of taxa recorded during benthic macroinvertebrate sampling in Tantangara Reservoir in January 2019.

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Oligochaeta	Worm	1123	75.5
Chironomidae	Insect	249	16.7
Nematoda	Worm	91	6.1
Corbiculidae/ Sphaeriidae	Mollusc	19	1.3
Hydracarina	Other	3	0.2
Hydridae	Other	2	0.1
Notonectidae	Insect	1	0.1

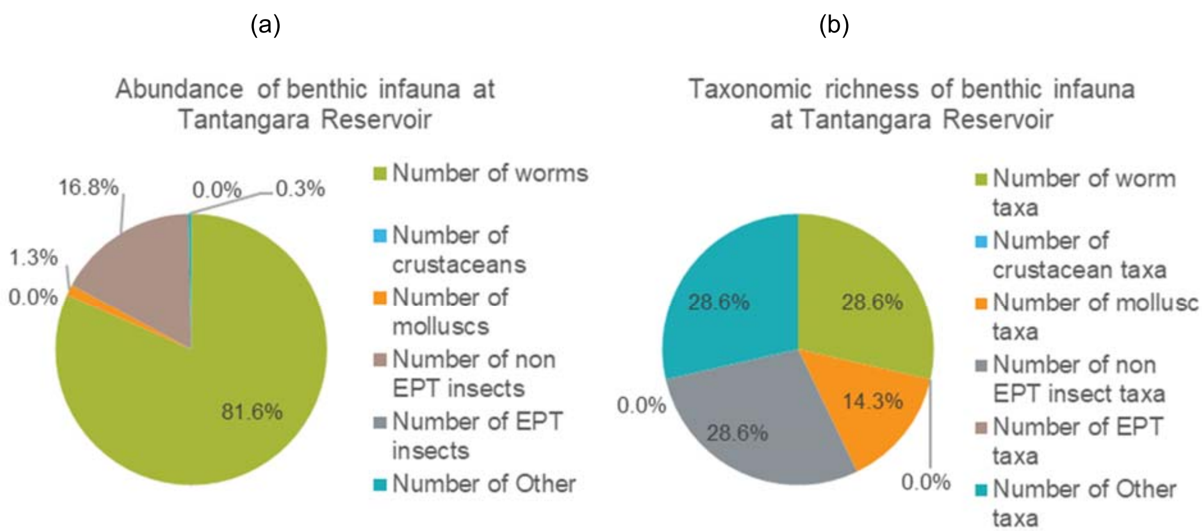


Figure 5-17 (a) Relative abundance and (b) taxonomic richness of major groups of benthic macroinvertebrates sampled in Tantangara Reservoir in January 2019.

In Tantangara Reservoir, mean total abundance was greatest at TS within the southern portion of the reservoir, water depth range of 14.1 m – 15.7 m (207.0 individuals ± 86.0) and lowest at TM South (51.0 individuals ± 17.0), within the middle portion of the reservoir, at a water depth between 13.8 m – 17.3 m. Mean taxon richness was lowest at TS, (3.0 ± 0.) and greatest at TN North (4.5 taxa ± 0.5) at the northern end of the main basin at a water depth of approximately 20 m (**Figure 5-18**).

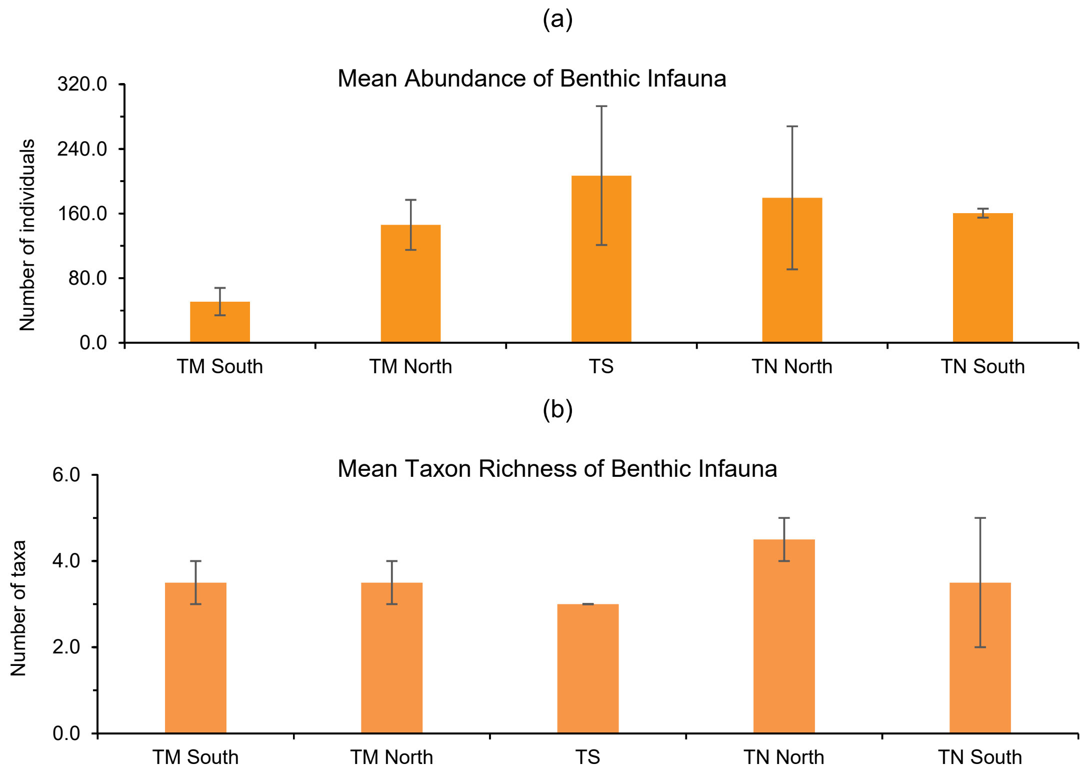


Figure 5-18 a) Mean abundance and b) mean taxon richness of benthic macroinvertebrate assemblages at each location sampled in Tantangara Reservoir in January 2019. TM = Tantangara Mid, TS = Tantangara South, TN = Tantangara North.

Multivariate statistical analysis indicated that the composition of the benthic infaunal assemblages at each of the five sampling locations within Tantangara Reservoir varied significantly ($p > 0.05$), although pairwise tests were unable to resolve where these differences occurred within the data. nMDS ordination analysis indicated that some locations were distinct from one another, with some separation apparent between assemblages within the different zones of the reservoir (i.e. south, mid and north) (**Figure 5-19**).

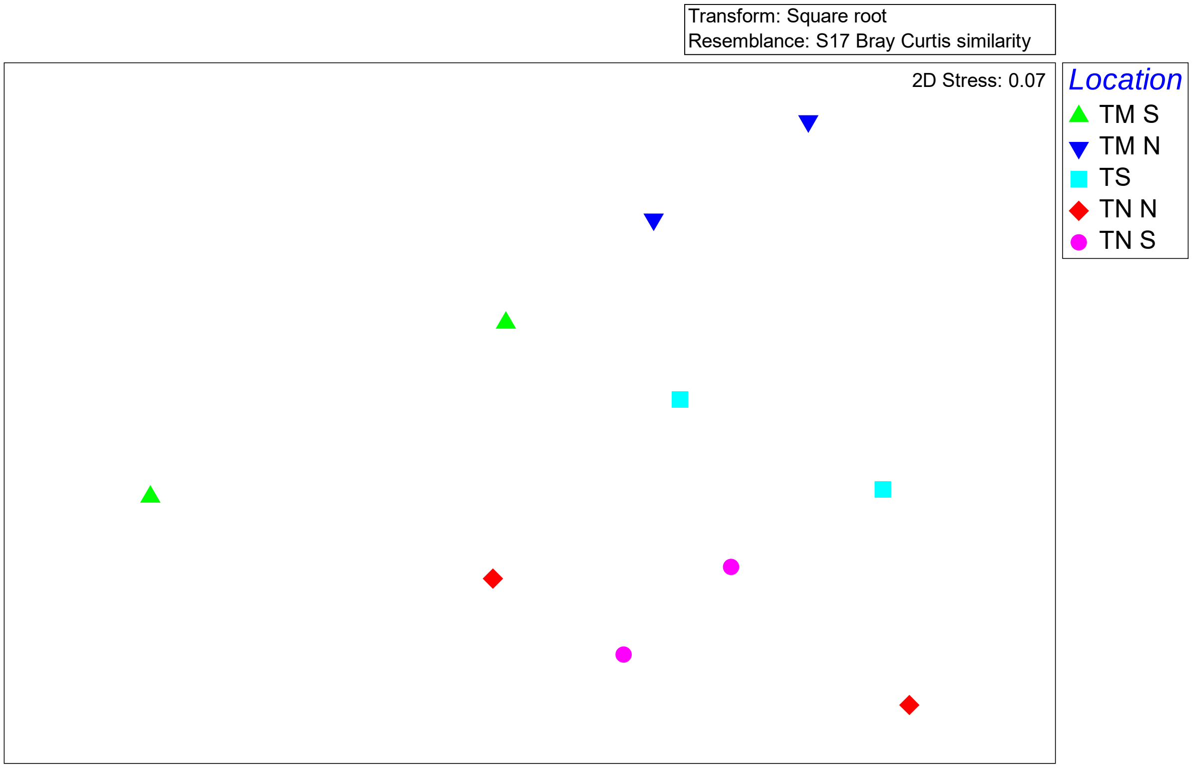


Figure 5-19 Two dimensional non-metric multi-dimensional (nMDS) scaling ordination for the composition of benthic macroinvertebrate assemblages collected from five locations within Talbingo Reservoir in January 2019. Distances between points indicate relative similarities among sampling locations.

5.4 Riffle Macroinvertebrates

A total of 4,652 individuals from 48 taxonomic groups (Family level or higher) were identified from the 25 samples collected from within riffle habitat in watercourses across the Ravine and Plateaux system in January/February 2018. Chironomidae (non-biting midges) were the most numerically abundant taxon, accounting for 18% of all individuals collected from the reservoir. Leptophlebiidae (mayflies), Elmidae (beetles), Baetidae (mayflies) and Hydropsychidae (caddis flies) accounted for 14%, 11%, 9% and 5% respectively, of all individuals collected (**Table 5-11**). All the other 43 taxa collected during the survey accounted for just over 43% of the total abundance of riffle macroinvertebrates within the Ravine/Plateaux System. A breakdown of the abundance and taxonomic richness of major taxonomic groups within Talbingo Reservoir is provided in **Figure 5-20**.

Table 5-11 Total abundance and percent contribution of the 10 most abundant taxa recorded during riffle macroinvertebrate sampling across the Ravine and Plateaux System in January/February 2018.

Order or Family	Major Group	Total Abundance	% Contribution to assemblage
Chironomidae	Insect	839	18.0
Leptophlebiidae	Insect (Ephemeroptera)	632	13.6
Elmidae	Insect	506	10.9
Baetidae	Insect (Ephemeroptera)	421	9.0
Hydropsychidae	Insect (Trichoptera)	239	5.1
Tipulidae	Insect	224	4.8
Psephenidae	Insect	182	3.9
Ceinidae	Crustacean	169	3.6
Hydrochidae	Insect	152	3.3
Oligochaeta	Annelid	112	2.4

(a) (b)

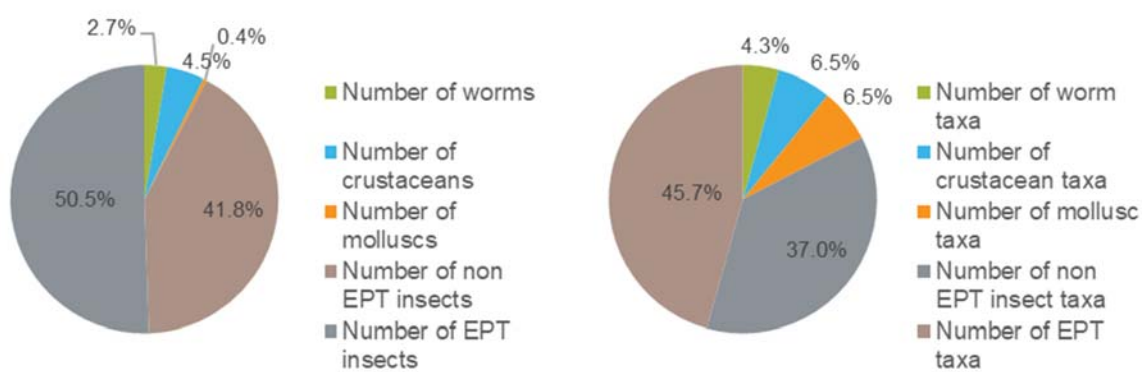
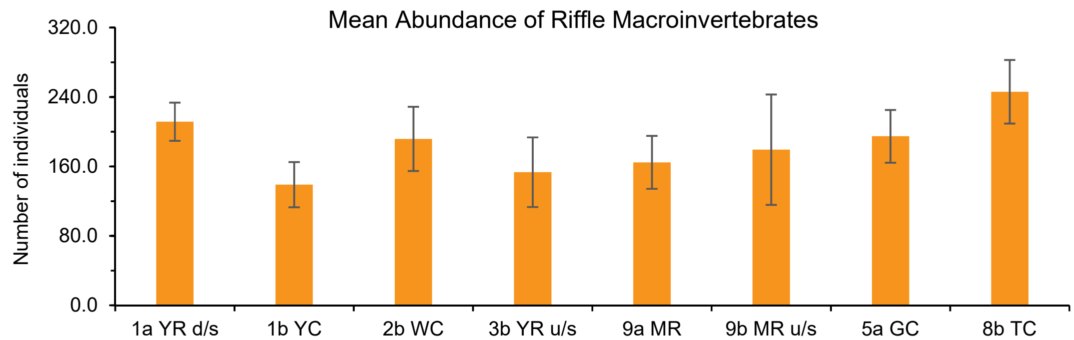


Figure 5-20 (a) Relative abundance and (b) taxonomic richness of major groups of benthic macroinvertebrates sampled in Tantangara Reservoir January/February 2018.

Mean total abundance within the Ravine/Plateaux watercourses was greatest at location 8b, on Tantangara Creek, approximately 1 km upstream of the confluence with Gooandra Creek (246.0 individuals ± 36.7) and lowest at location 1b, on the Yarrangobilly River in close proximity to the Yarrangobilly Caves (139.0 individuals ± 26.1). Mean taxon richness was lowest at location 5a (Gooandra Creek), with 16 taxa ± 1.0 recorded and greatest at location 2b (21.3 taxa ± 0.3) within Wallaces Creek, just upstream of the confluence with the Yarrangobilly River (**Figure 5-21**).

(a)



(b)

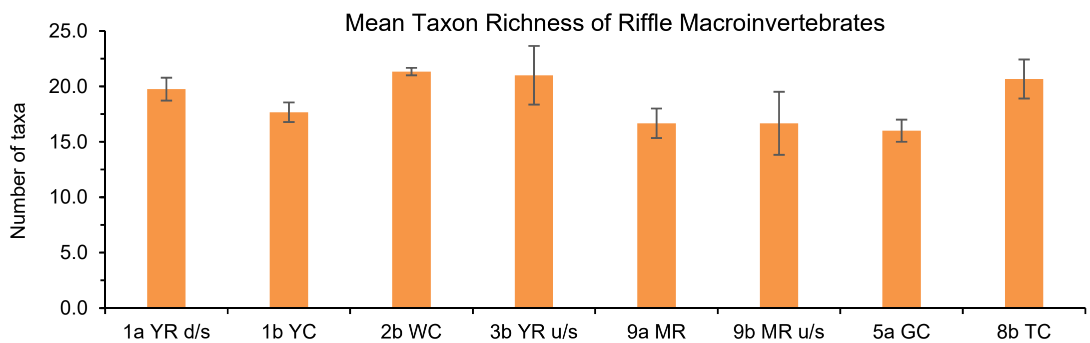


Figure 5-21 a) Mean abundance and b) mean taxon richness of riffle macroinvertebrate assemblages at each location sampled in January/February 2018. 1a = Yarrangobilly River at Lobs Hole, 1b = Yarrangobilly River at Yarrangobilly Caves, 3b = Yarrangobilly River at Highway Crossing, 2b = Wallaces Creek at Lobs Hole, 9a = Murrumbidgee River at Tantangara Creek Crossing, 9b = Murrumbidgee River at Port Phillip Trail5a = Gooandra Creek at trail crossing, 8b = Tantangara Creek at trail crossing, u/s = upstream, d/s = downstream.

Multivariate statistical analysis indicated that the composition of the riffle macroinvertebrate assemblages in watercourses situated within the Ravine/Plateaux System varied significantly among locations ($p < 0.001$), with pairwise tests indicating that assemblages at most locations differed significantly from one another. There appears to be some separation of assemblages within the upper Murrumbidgee River Catchment from those within the Yarrangobilly catchment, with locations 1a, 1b, 2b and 3b (Yarrangobilly locations) within the nMDS plot separated from locations 9a, 9b, 5b and 8b (Murrumbidgee locations) (**Figure 5-22**). Even within a particular catchment, assemblages at different locations are somewhat distinct from one another.

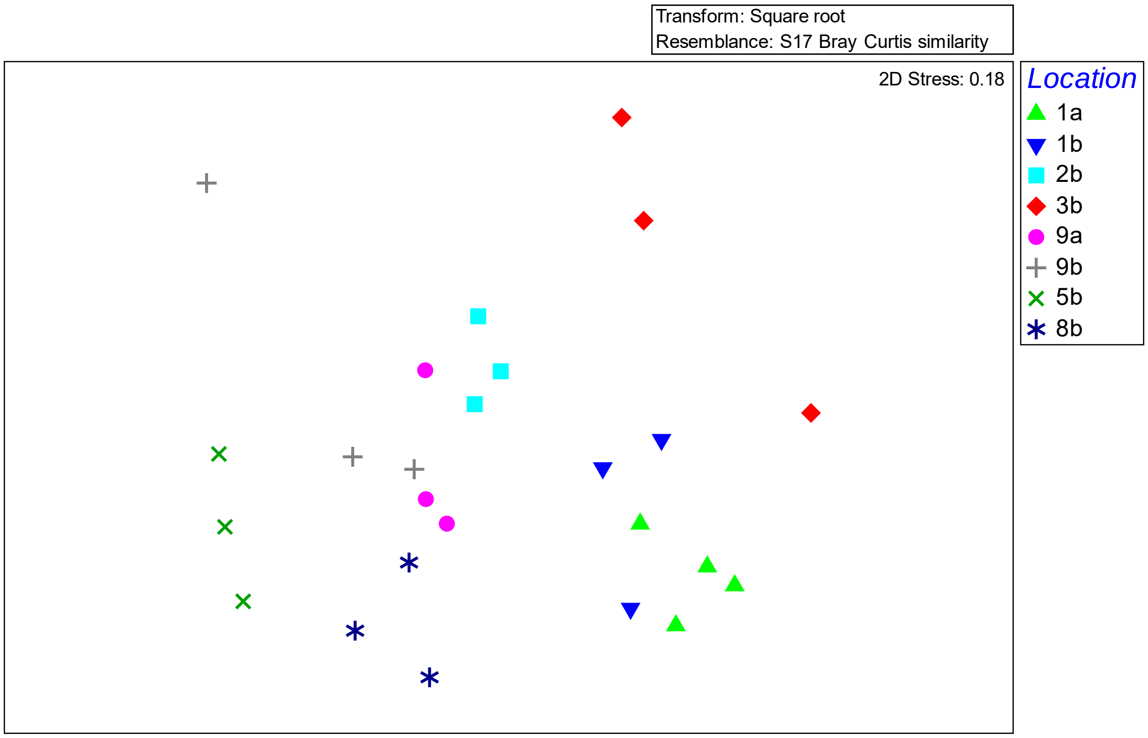


Figure 5-22 Two dimensional non-metric multi-dimensional (nMDS) scaling ordination for the composition of riffle macroinvertebrate assemblages collected from watercourses within the Ravine/Plateaux System in January/February 2018. Distances between points indicate relative similarities among sampling locations.

5.5 Phytoplankton

Comparison of phytoplankton assemblages between the two reservoirs for the two months when both reservoirs were sampled (March and May 2018) indicated significant differences (March: $p < 0.01$, May: $p < 0.001$) (**Figure 5-23**).

Phytoplankton assemblages did not vary among locations within reservoirs (March: $p = 0.163$, May: $p = 0.598$), indicating relatively homogeneous phytoplankton assemblages within each reservoir at each survey time.

Table 5-12 provides the average abundances for the five most abundant phytoplankton taxa. Several differences are evident between the two reservoirs, for example, *Woronichinia* spp. was sampled only in Tantangara Reservoir, and also tended to increase in abundance from March (19.98 cells/mL) to April (57.46 cells/mL) to May 2018 (80.11 cells/mL).

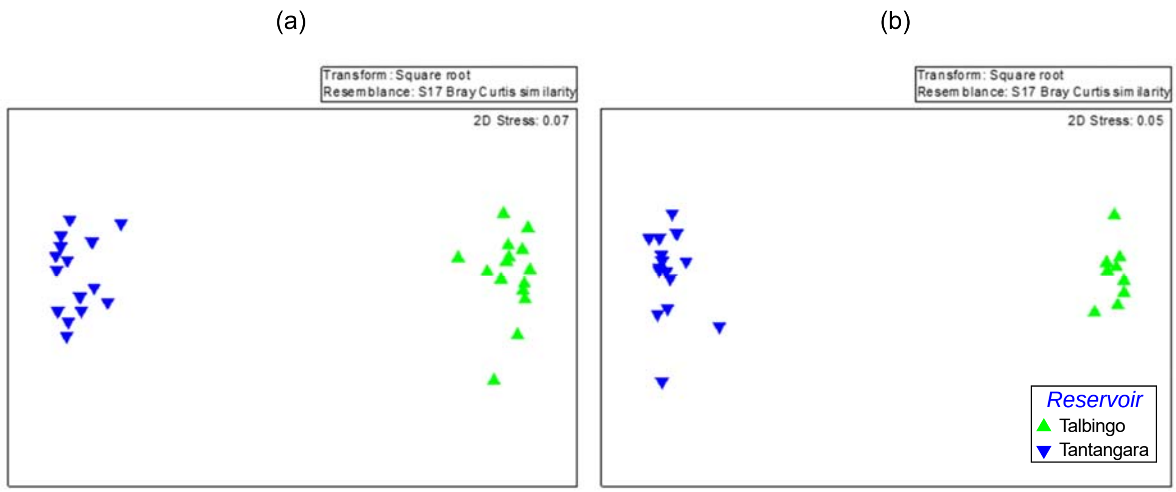


Figure 5-23 nMDS ordinations of phytoplankton assemblages within Talbingo and Tantangara reservoirs for (a) March 2018 and (b) May 2018.

Table 5-12 SIMPER results indicating the species that best discriminate between phytoplankton assemblages within Talbingo and Tantangara reservoirs in March 2018 and May 2018.

		Average Abundance	
Taxon	**Group**	**Talbingo Reservoir**	**Tantangara Reservoir**
March 2018			
***Melosira* spp.**	Bacillariophyta	18.21	51.31
***Cyanodictyon* spp.**	Cyanophyta	29.01	0.00
***Aphanothece* spp.**	Cyanophyta	20.66	0.00
***Woronichinia* spp.**	Cyanophyta	0.00	19.98
***Aphanocapsa* spp. Small (1 µm)**	Cyanophyta	15.34	10.73
May 2018			
***Woronichinia* spp.**	Cyanophyta	0.00	80.11
***Synechococcus* spp.**	Cyanophyta	31.96	0.00
***Aulacoseira* spp.**	Bacillariophyta	0.90	26.76
***Cyanodictyon* spp.**	Cyanophyta	22.40	0.00
***Aphanocapsa* spp. Small (1µm)**	Cyanophyta	22.15	1.36

Temporal differences in phytoplankton assemblage structure were shown to be significant for both reservoirs (Talbingo: p < 0,001, Tantangara: p < 0.001) (**Figure 5-24**).

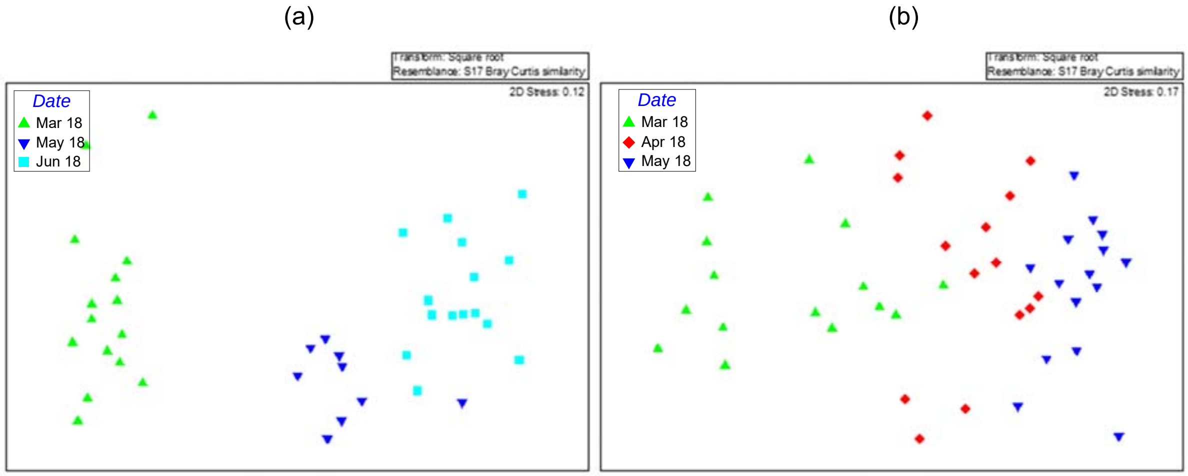


Figure 5-24 nMDS ordinations of phytoplankton assemblages within (a) Talbingo and (b) Tantangara reservoirs through the period March, April, May and/or June 2018.

As observed for the historical data (collected by Snowy Hydro) since 1998, the data collected in 2018 indicated that total phytoplankton abundance is generally greater within Tantangara Reservoir compared with Talbingo Reservoir (**Figure 5-25**). A significant difference in phytoplankton abundance between reservoirs was detected in May 2018 ($p < 0.01$). The difference in March 2018 was marginally non-significant ($p = 0.063$), with a mean abundance in Tantangara Reservoir (6140.00 cells/mL ± 567.43) almost double that sampled within Talbingo Reservoir (3542.67 cells/mL ± 490.50). Phytoplankton abundance generally increased from March to May/June in both reservoirs, with a greater abundance of phytoplankton sampled during the cooler months. A significantly greater abundance of phytoplankton was sampled in June 2018 within Talbingo Reservoir ($p < 0.01$), although no significant difference in phytoplankton abundance was detected among months within Tantangara Reservoir ($p = 0.09$), although there was an increasing trend in abundance though time (**Figure 5-25**).

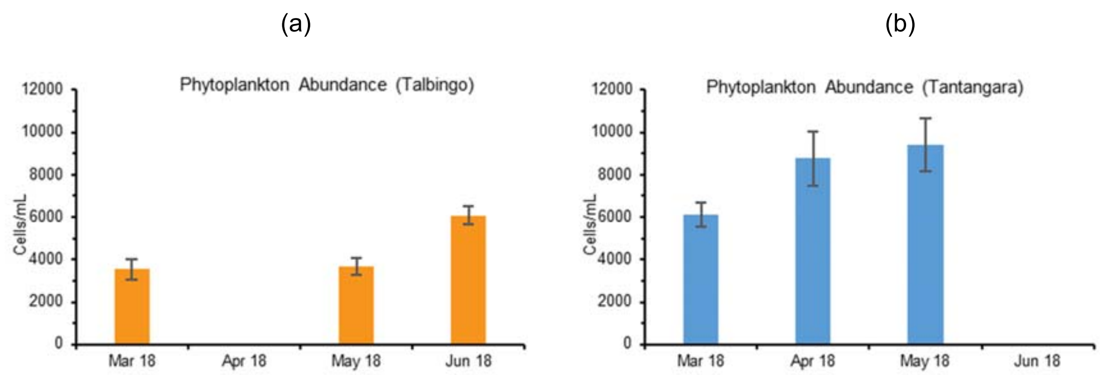


Figure 5-25 Mean abundance (±SE) of phytoplankton within (a) Talbingo and (b) Tantangara reservoirs throughout March, April, May and June 2018.

The mean number of phytoplankton taxa within the two reservoirs ranged between 11 and 15, with no significant differences detected in the number of taxa between the two reservoirs throughout the sampling program (March: $p = 0.10$, May: $p = 0.19$) (**Figure 5-26**). Similarly, no difference in the number of taxa was detected between sampling months within Tantangara Reservoir ($p = 0.664$), although a significant decrease in taxa within Talbingo Reservoir between May and June 2018 was detected ($p < 0.01$).

In total, 58 phytoplankton taxa were identified from the three surveys at each reservoir (**Table 5-13**), with 27 common to both reservoirs; 12 taxa and 15 taxa were found only in Talbingo Reservoir and Tantangara Reservoir, respectively. Of the 14 cyanophyte taxa (blue-green algae, some of which can cause harmful algal blooms) identified, only four were common to both reservoirs, with 3 taxa and 7 taxa found only in Talbingo Reservoir and Tantangara Reservoir respectively. Of these, *Dolichospermum circinale* in particular is known to be associated with HABs. This taxon was detected only in Talbingo Reservoir. Some species of *Woronichinia*, such as *Woronichinia naegeliana* are known to be associated with harmful algal blooms.

(a) (b)

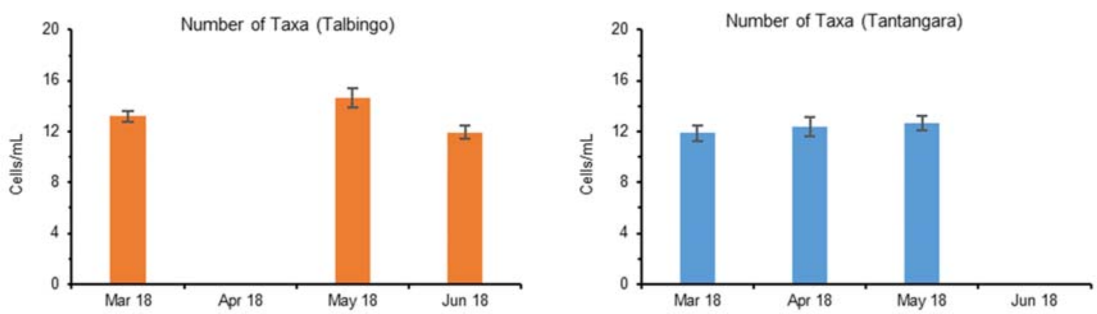


Figure 5-26 Mean number of phytoplankton taxa (±SE) within (a) Talbingo and (b) Tantangara reservoirs throughout March, April, May and June 2018.

Table 5-13 Mean number (plus 95 % confidence interval) of phytoplankton cells identified in all samples from March, May and June surveys in Talbingo Reservoir and from March April and May surveys in Tantangara Reservoir in 2018.

Taxon	Mean		95% Confidence Interval	
	Talbingo	Tantangara	Talbingo	Tantangara
Bacillariophyta				
Acanthoceros spp.	2.56	39.22	3.14	58.24
Asterionella spp.	11.05	3.89	9.76	6.28
Aulacoseira spp.	5.26	656.89	5.19	253.53
Fragilaria spp.	3.08	252.51	4.01	89.58
Melosira spp.	202.72	1021.84	68.66	394.21
Synedra spp.	9.26	0.38	4.42	0.76
Tabellaria spp.	0.44	245.87	0.88	86.75
Urosolenia spp.	29.87	0.00	8.68	0.00
Unidentified pennate diatoms	3.92	4.20	3.51	2.32
Unidentified centric diatoms	2.56	0.00	2.61	0.00
Bacillariophyta Subtotal	271.13	2199.78	74.15	442.50
Chlorophyta				
Ankistrodesmus spp.	0.00	1.11	0.00	1.65
Closterium spp.	0.00	0.11	0.00	0.22
Crucigenia spp.	13.33	2.98	9.94	4.20
Dictyosphaerium spp.	167.56	308.62	136.43	126.79
Fusola spp.	86.74	10.02	32.31	5.02
Euastrum spp.	0.00	0.11	0.00	0.22
Nephrocytium spp.	0.00	3.00	0.00	6.06
Monoraphidium spp.	1.28	0.38	1.89	0.76
Oocystis spp.	49.13	5.18	17.83	4.39
Mougeotia spp.	0.00	0.22	0.00	0.45
Selenodictyum spp.	6.79	0.00	9.83	0.00
Kirchneriella spp.	0.85	0.38	1.70	0.76
Planktonema spp.	0.00	1.91	0.00	3.86
Scenedesmus spp.	0.00	1.11	0.00	2.24
Sphaerocystis spp.	0.00	3.00	0.00	6.06
Staurastrum spp.	0.00	0.53	0.00	0.82
Unidentified Colonial Chlorophyta	93.85	50.80	69.12	37.33
Unidentified Unicellular Chlorophyta	238.79	105.73	41.91	41.67

Taxon	Mean		95% Confidence Interval	
	Talbingo	Tantangara	Talbingo	Tantangara
Chlorophyta Subtotal	658.59	499.18	156.58	137.84
Cyanophyta				
Synechococcales	0.00	0.00	0.00	0.00
Anathece spp.	419.74	299.73	300.59	230.73
Aphanocapsa spp. Small (1 µm)	469.41	506.78	155.19	398.33
Aphanocapsa spp. Large (2.5 µm)	10.64	0.00	21.39	0.00
Cyanodictyon spp.	626.18	29.56	363.91	59.70
Pseudanabaena galeata	0.00	15.22	0.00	19.98
Romeria spp.	6.00	0.00	5.99	0.00
Cyanogranis libera	6.79	0.00	13.66	0.00
Snowella spp.	162.67	0.00	124.78	0.00
Synechococcus spp.	1552.95	0.00	582.91	0.00
Woronichinia spp.	0.00	4231.87	0.00	1356.41
Synechococcales Subtotal	3255.00	5086.33	666.73	1375.62
Nostocales	0.00	0.00	0.00	0.00
*Dolichospermum circinale**	20.64	0.00	29.20	0.00
Unidentified Straight Nostocales	5.82	16.49	6.69	21.05
Nostocales Subtotal	26.41	16.44	32.65	20.97
Chroococcales	0.00	0.00	0.00	0.00
Aphanothece spp.	209.03	0.00	120.39	0.00
Myxobaktron spp.	11.54	0.00	14.22	0.00
Unidentified Chroococcales	0.00	0.77	0.00	1.52
Chroococcales Subtotal	220.49	0.73	127.62	1.48
Total Cyanophytes	3456.59	5103.44	643.25	1374.14
Cryptophyta				
Chroomonas spp.	108.08	83.20	35.10	29.27
Cryptomonas spp.	16.77	46.93	9.65	16.06
Unidentified Cryptophyta	0.00	1.11	0.00	2.24
Cryptophytes Subtotal	125.05	131.47	36.65	30.77
Chrysophyta				
Dinobryon spp.	10.15	12.91	9.74	10.46
Epipyxis spp.	1.28	16.60	1.89	9.58
Unidentified Chrysophyta	0.44	0.38	0.88	0.76
Chrysophyta Subtotal	11.82	29.84	9.76	17.35
Dinophyta				
Ceratium spp.	0.00	2.13	0.00	1.46
Gymnodinium spp.	1.95	0.00	1.56	0.00
Peridinium spp.	1.74	17.60	1.68	13.94
Unidentified Dinophyta	2.18	1.13	1.85	1.29
Dinophyta Subtotal	5.87	20.87	3.04	14.20
Euglenophyta				
Euglena spp.	0.13	0.00	0.26	0.00
Trachelomonas spp.	0.87	34.96	1.22	9.52
Unidentified Euglenophyta	0.00	1.49	0.00	1.80
Euglenophyta Subtotal	1.00	36.42	1.24	9.80

Taxon	Mean		95% Confidence Interval	
	Talbingo	Tantangara	Talbingo	Tantangara
Raphidophytes				
Unidentified Raphidophyta	6.72	4.75	2.87	2.62
Raphidophyta Subtotal	6.89	4.42	2.89	2.60
Synurophyta				
Mallomonas spp.	3.36	12.84	2.13	6.59
Synura spp.	1.72	1.84	3.45	3.73
Synurophyta Subtotal	5.08	14.69	3.90	7.27
Total Phytoplankton	4551.79	8107.02	654.27	1298.05

6 Likelihood of Occurrence

Based on a synthesis of literature and database reviews, results of eDNA surveys (EnviroDNA 2019 a, b) and field surveys, the likelihood of fish and crayfish species inhabiting the different catchments within the study area was based on criteria described in **Table 6-1.** The likely distribution of fish and crayfish species throughout the study area is summarised in **Table 6-2**.

Table 6-1 Likelihood of occurrence criteria

Likelihood of occurrence	Code	Criteria for Assessment of Occurrence
Low	**Low (X):**	Area within historical distribution with sporadic recent records (stocking or catch records), expert opinion and/or negative DNA detection or field survey results suggest species is not currently present.
	Low (P):	Within predicted distribution, however, strong evidence to suggest it is not currently present (based on expert opinion and/or negative DNA detection or field survey results; or
	Low (DNA):	DNA detected*, but unlikely to represent live fish (due to low relative abundance of DNA and / or low detection rate combined with the absence of previous records (for known recreationally targeted species) and none caught during current field surveys). DNA may be from inert source of material from outside the reservoir/catchment. Includes potential landlocked populations of catadromous fish (e.g. *Anguilla* sp.)
Moderate	**Mod (Adj):**	No recent records in the reservoir/catchment but suitable habitat is present (NSW DPI, 2016) with no barriers to movement from adjacent areas of known occurrences; or
	Mod (P):	Within predicted distribution range (NSW DPI, 2016), but no confirmed catch records. (A precautionary approach has been applied and a medium likelihood of occurrence used where the species cannot be categorised as absent or of low occurrence (see above).
ccursOccurs Combination	**Oc (X):**	Species recently recorded or stocked in the catchment and the catchment provides suitable habitat.
	Oc (DNA)	DNA detected and the area is within the currently expected species distribution. Recent records may not be available for non-recreationally important species.
	Oc (C)	Caught during current study.
	Oc (X +DNA)	Combination of Oc (X) and Oc (DNA) .
	Oc (X+C+DNA)	Combination of Oc (X), Oc (DNA) and Oc (C)

*DNA detections at low relative abundance (≤ 1 % relative abundance) reported by EnviroDNA (2019a) represent a low likelihood of occurrence of live individuals in the absence of historical catch records or catches during project field surveys.

Table 6-2 Likelihood of occurrence of fish and crayfish species in the study area based on catch data and eDNA data, findings of the literature review and field surveys.

Scientific Name		Common Name	Tumut River Catchment						Murrumbidgee River Catchment					Snowy River Catchment			Murray River Catchment		
			Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River to Hume Reservoir Catchment	Swampy Plain River Catchment	Geehi Reservoir and M2 Reservoir Catchments
Threatened Species																			
Percichthyidae	*Macquaria australasica*	Macquarie perch (FM & EPBC Acts: End.)	Low (X)		Low (P)	Low (P)	Low (X)	Oc (X)	Low (P)	Low (P)		Oc (X+DNA)	Oc (X)				Oc (X)		
Percichthyidae	*Maccullochella macquariensis*	Trout cod FM & EPBC Acts: End.)	Oc (X)		Mod (Adj)	Mod (Adj)						Oc (X)	Oc (X)				Oc (X)		
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)					Oc (X+DNA)	Mod (Adj)				Oc (X)	Oc (X)				Oc (X)	Oc (X)	
Percichthyidae	*Gadopsis marmoratus*	River blackfish – Snowy River Catchment Population (FM Act: End.)													Mod (P)	Oc (X)			
Percichthyidae	*Nannoperca australis*	Southern pygmy perch (FM Act: End.)										Mod (P)				Oc (X)	Oc (X)		
Percichthyidae	*Bidyanus bidyanus*	Silver perch (FM Act: Vul.)					Oc (X)	Mod (Adj)					Oc (X)						
Galaxiidae	*Galaxias tantangara*	Stocky galaxias (FM Act: Crit. End.)									Oc (X)								
Plotosidae	*Tandanus tandanus*	Eel-tailed catfish - Murray-Darling Basin Population (FM Act: End.)											Oc (X)						
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)	Oc (X+C+DNA)	Oc (X)	Mod (Adj)	Oc (X+C+DNA)	Oc (X)	Oc (X)				Oc (X)	Oc (X)				Oc (X)	Oc (X)	
Odonata	*Austropetalia tonyana*	Alpine redspot dragonfly (FM Act: Vul.)													Mod (P)			Oc (X)	Mod (P)
Non-threatened Native Species																			
Percichthyidae	*Macquaria ambigua*	Golden perch	Low (DNA)				Oc (X+DNA)	Oc (X)				Oc (X)	Oc (X)				Oc (X)		

Scientific Name		Common Name	Tumut River Catchment						Murrumbidgee River Catchment					Snowy River Catchment			Murray River Catchment		
			Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River to Hume Reservoir Catchment	Swampy Plain River Catchment	Geehi Reservoir and M2 Reservoir Catchments
Percichthyidae	*Gadopsis marmoratus*	(Northern) River blackfish						Oc (X)									Oc (X)		
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish	Oc (X+DNA)		Mod (Adj)	Oc (X+DNA)	Oc (X+DNA)	Oc (X)				Oc (X)	Oc (X)				Oc (X)	Oc (X)	
Galaxiidae	*Galaxias olidus*	Mountain galaxias*	Oc (DNA)	Oc (X)	Mod (Adj)	Oc (X)	Oc (X)		Oc (DNA)	Oc (C+DNA)		Oc (X+C+DNA)	Oc (X)		Oc (X)	Oc (X)	Oc (X)	Oc (X)	
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Mod (Adj)			Oc (X+C+DNA)	Oc (X)							Oc (DNA)	Oc (DNA)	Oc (X)	Oc (X)	O	Oc (X+DNA)
Galaxiidae	*Galaxias terenasus*	Roundsnout galaxias														Oc (X)			
Galaxiidae	*Galaxias maculatus*	Common galaxias														Oc (X)			
Galaxiidae	*Galaxias arcanus*	Riffle galaxias															Oc (X)		
Retropinnidae	*Retropinna semoni*	Australian smelt	Low (DNA)					Oc (X)				Oc (X)	Oc (X)		Oc (X)	Oc (X)	Oc (X)	Oc (X)	
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon	Oc (DNA)		Mod (Adj)	Mod (Adj)	Oc (X+DNA)	Oc (X)				Oc (X)	Oc (X)	Oc (DNA)	Mod (Adj)	Oc (X)	Oc (X)	Mod (Adj)	
Eleotridae	*Philypnodon macrostomus*	Dwarf flathead gudgeon											Oc (X)				Oc (X)		
Eleotridae	*Hypseleotris* spp.	Carp gudgeon						Oc (X)				Oc (X)	Oc (X)				Oc (X)		
Anguillidae	*Anguilla australis*	Shortfinned eel	Low (DNA)						Low (DNA)							Oc (X)			
Anguillidae	*Anguilla reinhardtii*	Longfinned eel												Low (X)		Oc (X)			
Parastacidae	*Cherax* spp.	Common yabbie	Oc (C+DNA)	Oc (X)	Mod (Adj)	Mod (Adj)	Oc (DNA)	Mod (Adj)	Oc (C+DNA)	Oc (DNA)		Oc (X+C+DNA)	Mod (Adj)	Oc (X+DNA)	Oc (X)	Oc (X)	Oc (X)	Oc (X)	
Parastacidae	*Euastacus reiki*	Reik's crayfish							Oc (DNA)	Oc (X+C+DNA)	Mod (Adj)	Oc (X)		Oc (C+DNA)	Oc (X)				
Parastacidae	*Euastacus crassus*	Alpine spiny crayfish						Oc (X)								Oc (X)	Mod (Adj)	Oc (X)	Mod (Adj)
Parastacidae	*Euastacus* sp.	Unidentified spiny crayfish***				Oc (DNA)													

Scientific Name		Common Name	Tumut River Catchment						Murrumbidgee River Catchment					Snowy River Catchment			Murray River Catchment		
			Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River to Hume Reservoir Catchment	Swampy Plain River Catchment	Geehi Reservoir and M2 Reservoir Catchments
Parastacidae	*Engaeus cymus*	Burrowing crayfish					Oc (X)	Oc (X)										Oc (X)	
Palaemonidae		Freshwater prawn										Oc (DNA)							
Atyidae		Freshwater glass shrimp	Oc (DNA)				Low (DNA)					Oc (DNA)							
Non-Native Species																			
Percidae	*Perca fluviatilis*	Redfin perch	Oc (X+C+DNA)		Oc (X+DNA)	Oc (X+C+DNA)	Oc (X+DNA)	Oc (X)					Oc (X+DNA)			Oc (X)	Oc (X)	Oc (X+DNA)	
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Oc (X+C+DNA)				Oc (DNA)	Oc (X)				Oc (X+DNA)	Oc (X+DNA)	Low (DNA)	Low (DNA)	Oc (X)	Oc (X)		
Cypriniforme	Cypriniforme OTU1	Cypriniforme OTU1	Low (DNA)																
Cypriniforme	Cypriniforme OTU2	Cypriniforme OTU2	Low (DNA)				Low (DNA)			Low (DNA)									
Cypriniforme	Cypriniforme OTU3	Cypriniforme OTU3	Low (DNA)																
Cyprinidae	*Carassius auratus*	Wild goldfish	Oc (X+C+DNA)				Oc (DNA)	Oc (X)				Oc (X+DNA)	Oc (X)	Oc (X)	Oc (X)	Oc (X)	Oc (X)		
Cyprinidae	*Cyprinus carpio*	Carp	Low (DNA)					Oc (X)				Oc (X+DNA)	Oc (X)			Oc (X)	Oc (X)	Oc (X)	
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach						Oc (X)				Oc (X)	Oc (X)	Oc (X)	Oc (X)				
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Oc (X+C+DNA)	Oc (X)	Oc (X)	Oc (X+C+DNA)	Oc (X+DNA)	Oc (X)	Oc (X+C+DNA)	Oc (X+C+DNA)		Oc (X+C+DNA)	Oc (X)	Oc (X+DNA)	Oc (X)	Oc (X)	Oc (X)	Oc (X)	Oc (X)
Salmonidae	*Salmo trutta*	Brown trout	Oc (X+C+DNA)	Oc (X)	Oc (X)	Oc (X+C+DNA)	Oc (X+DNA)	Oc (X)	Oc (X+C+DNA)	Oc (X+C+DNA)		Oc (X+C+DNA)	Oc (X)	Oc (X+DNA)	Oc (X)	Oc (X)	Oc (X)	Oc (X)	Oc (X)
Salmonidae	*Salmo salar*	Atlantic salmon													Oc (X)			Oc (X)	
Salmonidae	*Salvelinus fontinalis*	Brook trout		Oc (X)										Oc (X+DNA)	Oc (X)				

Key: Vul. = Vulnerable, End. = Endangered, Crit. End. = Critically Endangered

*Specimens caught in the Upper and Mid Murrumbidgee River were identified tentatively as *Galxias olidus* (Raadik, 2018). It is unclear if the level of morphological differences identified represent previously unrecorded levels of diversity within this species or potentially undescribed species (Raadik, 2018). Occurrence in Talbingo Reservoir based on presence of *Galaxias* haplotype 1 detected by EnviroDNA (2019a) assumed to represent mountain galaxias based on know distributions of galaxiid (Raadik, 2014).

**Only three species of *Euastacus* are known to occur within the study area (Morgan 1997; Shulle et al., 2005 in EnviroDNA 2019a) haplotype for third species of spiny crayfish unconfirmed due to absence of reference material.

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ATTACHMENT

A

SAMPLING LOCATIONS

Table A1. GPS Coordinates (GDA 94) of boat-based electrofishing surveys in Talbingo Reservoir and Tantangara Reservoir in February 2018.

Location	Latitude	Longitude
Talbingo Reservoir		
Landers Creek	-35.658887	148.325310
Honeysuckle Creek	-35.681760	148.302700
Lick Hole Creek	-35.703728	148.333383
Middle Creek	-35.761395	148.368662
Yarrangobilly River	-35.773805	148.382192
Tumut River	-35.816591	148.365516
Tantangara		
Murrumbidgee River 1	-35.753545	148.643048
Murrumbidgee River 2	-35.751290	148.632437
Murrumbidgee River 3	-35.757964	148.617259
Nungar Creek	-35.761073	148.639058
Mosquito Creek 1	-35.743224	148.654231
Mosquito Creek 2	-35.734191	148.659788
Shoreline 1	-35.753940	148.664636
Shoreline 2	-35.774098	148.646939
Shoreline 3	-35.775268	148.661154
Shoreline 4	-35.786685	148.650188

Table A2. GPS Coordinates (GDA 94) and times of gill net deployments in Talbingo Reservoir on 11 – 13 September 2018.

Location	Date	Time	Rep	Approx. Depth	GPS Position (GDA 94)	
				(m)	Eastings	Northings
Talbingo Spillway/Proposed Barge Ramp	11/09/2018	9:30	1	5 – 25	148.2954209	-35.62610618
		9:30	2	5 – 25	148.2961403	-35.62476542
		10:20	3	5 – 25	148.2988676	-35.62363566
		11:30	4	5 – 25	148.3000043	-35.62433208
Dam Wall	13/09/2018	17:10	1	10 – 25	148.3001764	-35.6236641
Plain Creek Bay	13/09/2018	10:00	1	6 - 10	148.3460652	-35.75618039
		10:10	2	9 - 13	148.3453827	-35.75666472
		10:20	3	9 - 13	148.3413869	-35.76110122
		10:40	4	3 – 9.5	148.3418359	-35.76029442
		11:00	5	3 13	148.3464811	-35.75611061
Cascade Bay	12/09/2018	13:30	1	3 - 8	148.3218879	-35.74303847
		13:45	2	7 - 12	148.3216018	-35.74295047
		14:10	3	5 - 12	148.319455	-35.74360476
		14:20	4	4 - 12	148.3203485	-35.74370895
		15:00	5	10 - 12	148.3211929	-35.74309024
	12/09/2018	10:00	1	5 - 7	148.3823427	-35.77312554

Middle Arm Dredge Area/Proposed Barge Ramp		10:30	2	5 - 10	148.3790469	-35.77311913
		10:45	3	5 - 10	148.3737879	-35.76999307
		11:00	4	5 -10	148.3754812	-35.76962904
Honeysuckle Bay	11/09/2018	16:20	1	Approx. 40	148.3073817	-35.68052073
		16:30	2	Approx. 40	148.3097639	-35.68060805
Bay near Glendower Creek	13/09/2018	14:10	1	2 - 12	148.3375929	-35.70209355
		14:20	2	3 - 14	148.337149	-35.70238324
		15:00	3	4 - 28	148.3301721	-35.70289034
		15:03	4	5 - 25	148.3334684	-35.70329669

Table A3: Summary of catch data for gill net deployments undertaken in Tantangara Reservoir on 11 – 13 September 2018.

Location	Date	Time	Rep	Approx. Depth (m)	GPS Position (GDA 94) Eastings	Northings
Tantangara South (Intake)	31/10/2018	9:13	1	2-4	148.653697	-35.79674399
		9:24	2	2-5	148.654087	-35.79572702
		9:35	3	2-6	148.65425	-35.79280903
		9:45	4	2-10	148.656258	-35.79242698
		9:56	5	2-13	148.657286	-35.79110901
		10:07	6	2-8	148.655875	-35.78933397
		14:27	7	5-24	148.661025	-35.793192
		14:36	8	4-14	148.659565	-35.79429899
Tantangara Mid	31/10/2018	14:05	1	1-4	148.650399	-35.77745397
		14:23	2	1.5-3.5	148.649414	-35.76845298
		14:38	3	16	148.658274	-35.76650896
		14:53	4	16-14	148.659516	-35.76166003
		15:06	5	2-5	148.661651	-35.76824603
		15:20	6	2-5	148.658852	-35.78066499
Upper Murrumbidgee River/Nungar Creek	1/11/2018	8:41	1	4	148.638945	-35.76082502
		8:52	2	2-8	148.645133	-35.75477698
		9:02	3	6-8	148.639878	-35.75227297
		9:13	4	4-6	148.636704	-35.74829098
		9:25	5	4-9	148.649624	-35.75213601
		9:36	6	2-11	148.650743	-35.74842802

ATTACHMENT

B

RCE ASSESSMENT CRITERIA

Table B1: RCE Criteria

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		8. Riffle / pool sequence	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		9. Retention devices in stream	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		10. Channel sediment accumulations	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		11. Stream bottom	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / silt	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		12. Stream detritus	
Banks fully stabilised by trees, shrubs etc.	4	Mainly un-silted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc.	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6. Bank undercutting		13. Aquatic vegetation	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and algal growth	1
7. Channel form			
Deep: width / depth ratio < 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio > 15:1	2		
Artificial: concrete or excavated channel	1		

Table B2: Summaries RCE results.

Site	Land use pattern beyond the immediate riparian zone	Width of riparian strip of woody vegetation	Completeness of riparian strip of woody vegetation	Vegetation of riparian zone within 10 m of channel	Stream bank structure	Bank undercutting	Channel form	Riffle/pool sequence	Retention devices in stream	Channel sediment accumulations	Stream bottom	Stream detritus	Aquatic vegetation	Total
Yarrangobilly River Catchment														
1a	3	3	3	3	4	4	3	4	3	4	4	4	4	46
2a	4	4	4	4	4	4	4	4	4	4	4	4	4	52
4	3	4	3	3	4	4	4	2	3	1	2	3	4	40
10	3	4	4	3	4	4	4	n/a	3	4	4	4	n/a	37
13	3	4	3	3	4	4	4	2	3	1	2	3	4	40

ANNEXURE

C

ASSESSMENT OF SIGNIFICANCE

Cardno®

Annexure C – Assessment of Significance

Snowy 2.0 Main Works

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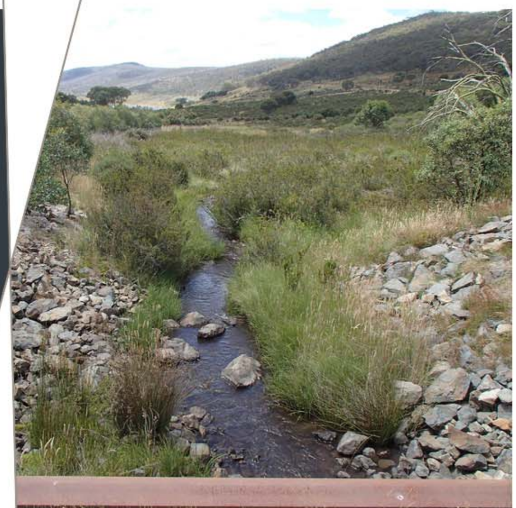

Prepared for
EMM Consulting Pty Ltd

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Rev 0

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Our report is based on information made available by the client. The validity and comprehensiveness of supplied information has not been independently verified and, for the purposes of this report, it is assumed that the information provided to Cardno is both complete and accurate. Whilst, to the best of our knowledge, the information contained in this report is accurate at the date of issue, changes may occur to the site conditions, the site context or the applicable planning framework. This report should not be used after any such changes without consulting the provider of the report or a suitably qualified person.

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Tables

1 Assessments of Significance (Fisheries Management Act 1994)

Section 220ZZ of the *Fisheries Management Act 1994* (FM Act) outlines significant impact considerations to threatened species, populations and ecological communities listed under the FM Act. Guidelines for the 7-part test are outlined in the *Threatened Species Assessment Guidelines: The Assessment of Significance.*

The following FM Act listed entities are considered to be present or to have suitable habitat and a potential to occur within the study area:

> Macquarie perch (*Macquaria australasica*) – Listed as endangered under the FM Act;
> Trout cod (*Maccullochella macquariensis*) – Listed as endangered under the FM Act;
> River blackfish – Snowy River Catchment Population (*Gadopsis marmoratus*) – Listed as endangered under the FM Act;
> Southern pygmy perch (*Nannoperca australis*) – Listed as endangered under the FM Act;
> Silver perch (*Bidyanus bidyanus*) – Listed as vulnerable under the FM Act;
> Stocky galaxias (*Galaxias tantangara*) - Listed as critically endangered under the FM Act;
> Murray Darling population of eel tailed catfish (*Tandanus tandanus*) – listed as an endangered population under the FM Act;
> Alpine redspot dragonfly (*Austropetalia tonyana*) – listed as vulnerable under the FM Act; and
> Murray crayfish (*Euastacus armatus*) - Listed as vulnerable under the FM Act.
> Snowy River Endangered Ecological Community (EEC).

Each species / population / EEC was assessed in terms of their likelihood to occur in areas potentially affected directly or indirectly by the project. As will be discussed within the following sections, many of these are not considered to be present in the direct project area. For the purpose of the aquatic ecology assessment the study area was delineated into catchments based on the ecological and geographic context, hydrological connectivity, aquatic habitat types and the known distribution of key species. A conservative approach has been taken whereby the immediate project area, encompassing the area with the potential for direct impacts to aquatic fauna, has been expanded to include a much broader 'Study Area'. This enabled a more complete assessment and inclusion of areas with the potential to be indirectly affected by the project due to water transfers or downstream releases from the project area. The definitions and extent of these catchments is indicated in **Figure 5-1** of the main report.

1.1 Macquarie perch (*Macquaria australasica*)

This species is listed as endangered under the FM Act.

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

Macquarie perch occurs in the Murray-Darling Basin, particularly the upstream reaches of the Lachlan, Murrumbidgee and Murray rivers, and parts of south eastern coastal NSW, including the Hawkesbury and Shoalhaven catchments (NSW DPI, 2018). It prefers clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks and it is found in both river and lake habitats, especially in the upper reaches of rivers and their tributaries (DPI 2016b). It spawns in spring or summer and lays eggs over stones and gravel in shallow, fast-flowing upland streams or flowing parts of rivers. Macquarie perch inhabiting impoundments would likely undertake upstream spawning migration from October to mid-January after which adults usually return to the impoundments. Migration may not be necessary in stream-dwelling fish. The Macquarie perch is an active predator of macroinvertebrates.

Within the study area, based on an extensive synthesis of literature and database reviews, results of eDNA surveys (EnviroDNA 2019a, b) and field surveys for the Snowy 2.0 project, it has been deemed that Macquarie perch occur within the Lower Tumut River Catchment (below Blowering Reservoir), within the Mid and Lower Murrumbidgee River Catchments and within the Murray River Catchment to Hume Reservoir. It is not considered present in Talbingo or Tantangara reservoirs or any of the other waterways with the potential to be directly affected by construction activities associated with Snowy 2.0.

Based on information presented in **Table 1-1** and **Table 1-2**, project activities that have the potential to affect this species within the Mid Murrumbidgee River Catchment are from the transfer of water between Talbingo and Tantangara reservoirs. No impacts on Macquarie perch from Snowy 2.0 are expected in the other catchments listed above. The impacting processes from this activity with regards to Macquarie perch are discussed below.

> Indirect - Impact of fish transfer on fish ecology

The potential impact of fish transfer on Macquarie perch relates to the potential transfer of redfin perch into Tantangara Reservoir from Talbingo Reservoir and ultimately into the Mid Murrumbidgee River below Tantangara dam wall, where Macquarie perch are known to occur and redfin perch are currently considered absent. Redfin perch have been linked with the decline in numbers of Macquarie perch (ACT Gov. pers. comm., 2017, cited in NSW DPI 2018) through competition for food, such as fish larvae and aquatic macroinvertebrates, and via direct predation on Macquarie perch larvae and juveniles.

The proposed addition of a fish barrier control on Tantangara dam wall as part of Snowy 2.0 would aim to prevent the transfer of redfin perch (and other fish) from Tantangara Reservoir should they establish there following the connection of the two reservoirs.

This would reduce the likelihood of redfin perch being transferred to the Mid-Murrumbidgee catchment where Macquarie perch are located.

As part of the fish transfer impact assessment, the residual risk to Macquarie perch following the implementation of the barrier control would be moderate (**Section 7.2.3** of main report).

> Indirect - plant and phytoplankton transfer leading to harmful algal blooms (HABs)

The transfer of water from Talbingo Reservoir into Tantangara Reservoir has the potential to change the distribution and abundance of phytoplankton assemblages within Tantangara Reservoir and therefore potentially within the Mid Murrumbidgee River downstream of the Tantangara dam wall (via environmental releases).

Some phytoplankton taxa occur in Talbingo Reservoir but not in Tantangara Reservoir, including the HAB taxa *Dolichospermum circinale*. Given the large volumes of water that could potentially be transferred on a regular basis, it is predicted assemblages of phytoplankton could become more similar in each reservoir, with an increase in HAB taxa from one taxon in each reservoir to two in each. For this to have an impact on the population of Macquarie Perch in the mid-Murrumbidgee catchment, as well as being transferred from Talbingo to Tantangara, volumes of HAB taxa would have to increase well above levels historically identified in either reservoir which is considered unlikely given the landuse attributes and temperature profiles of these reservoirs. These high volumes of taxa, should they occur, would then have to be transferred through the dam and remain in the river in sufficient quantities to affect water quality through toxic by-products or low dissolved oxygen to cause fish injury or mortality.

In general, however, HABs would be expected to be less likely to occur in watercourses given that flowing water environments would be less suitable for the proliferation of phytoplankton, although they do occur at least in slower flowing lowland rivers.

As part of the plant and phytoplankton transfer impact assessment, the residual risk to Macquarie perch following the implementation of the barrier control would be low (see **Section 7.2.4** of main report).

> Indirect - Proliferation of non-native aquatic plants

Elodea was recorded in both reservoirs during surveys for this project, although it was significantly more abundant in Talbingo. The reasons for the difference in relative abundance could not be established but could be due to physical differences between the reservoirs (see Physical Limnology Repot (Cardno, 2019)).

As this species has been observed in Tantangara Reservoir in the past, there is already an existing risk that elodea may already be present or become established in the mid-Murrumbidgee River at some point in the future, even in the absence of Snowy 2.0, although the high abundance of this species in Talbingo means that water transfer could deliver additional propagules to Tantangara Reservoir.

In addition, elodea is considered more suited to slow-moving or stationary water (DPI, 2019) so it is unlikely that Snowy 2.0 would materially alter the existing risk of elodea transfer from Tantangara Reservoir into the Mid Murrumbidgee River and for this to lead to an impact to Macquarie Perch in this catchment.

As such, the proliferation of non-native aquatic plants is considered a low risk to the Macquarie perch population within the Mid Murrumbidgee River (see **Section 7.2.4** of the main report).

> Indirect - Fish disease transfer leading to mortality

The main fish disease with relevance to the project is EHNV (**Section** Error! Reference source not found.. of the main report). Although outbreaks of EHNV are rare and EHNV has not been previously detected in either Talbingo or Tantangara reservoirs, as redfin perch, the primary vector for this disease is present in Talbingo, there is potential for EHNV to be present in very low quantity or establish within the reservoir at some point in the future. In the event that Snowy 2.0 leads to the transfer and establishment of redfin in the future, this would lead to an increase in the risk of an outbreak of EHNV within Tantangara Reservoir. If an outbreak occurs within Tantangara Reservoir, water released from the dam into the Mid Murrumbidgee River may contain the disease. As Macquarie perch have been shown to be susceptible to EHNV under laboratory conditions, it is possible that these fish could be affected if they were to come in contact with the disease, although there are no recorded instances of Macquarie perch infection with EHNV from the wild (Hick et al, 2019).

Given the apparently diminishing frequency of EHNV outbreaks and the fact that EHNV has not been recorded to date in Talbingo Reservoir, the likelihood of an EHNV outbreak in Tantangara Reservoir, should redfin perch establish there, is considered possible. The likelihood of an outbreak of EHNV subsequently spreading to the Mid Murrumbidgee River and affecting the population of Macquarie perch present is considered unlikely following installation of the fish barrier which is expected to substantially decrease the viral load (associated with infected fish) entering the catchment in the unlikely event of an outbreak of EHNV in Tantangara Reservoir.

As such, it has been assessed that the residual risk to Macquarie perch within the Mid Murrumbidgee River from an outbreak of EHNV is low (**Section 7.2.5** of the main report).

The following mitigation measures are considered relevant to mitigating or reducing the risk of harm from the processes listed above to populations of Macquarie perch in the Mid Murrumbidgee River as part of Snowy 2.0:

AE01: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat; and

AE22: Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel.

Based on the above assessments, project activities within these catchments would not be expected to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Table 1-1 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-2 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Macquarie perch**	Low		Low	Low	Low	Oc	Low	Low		Oc	Oc				Oc		
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

   i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

   ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

   i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

   ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

   iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-2**, the extent of impacts to Macquarie perch habitat as per criteria d) i-iii are addressed and summarised in **Table 1-3** below.

Table 1-3 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Mid Murrumbidgee River Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	No direct impacts to habitat important to Macquarie perch are expected	Potential impacts are associated with indirect effects of water transfer between Talbingo and Tantangara reservoirs.
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to Macquarie perch are expected to result in the fragmentation or isolation of habitat	Potential impacts are associated with indirect effects of water transfer between Talbingo and Tantangara reservoirs.
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	No habitat will be directly removed, modified or fragmented.

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This issue is not applicable, as no critical habitat has been listed for the Macquarie perch.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

The NSW DPI Priorities Action Statement (PAS) – Actions for the Macquarie Perch and the National Recovery Plan for Macquarie Perch (*Macquaria australasica*), Commonwealth of Australia 2018 identifies actions and strategies for the recovery of Macquarie perch.

https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/endangered-species/macquarie-perch/priorities-action-statement-actions-for-macquarie-perch

https://www.environment.gov.au/biodiversity/threatened/publications/recovery/macquaria-australasica-2018

These recovery objectives and actions mostly surround conservation works, research and monitoring, agency consultation and community engagement.

Potential impacts from Snowy 2.0 that are related to these objectives and actions mostly include the potential interaction of Macquarie perch with introduced fish species (i.e. redfin perch) and the protection of Macquarie perch from the outbreak of disease.

The mitigation measures listed above in Section (a) are expected to reduce the likelihood of a potential impact to Macquarie perch and are considered consistent with the actions and objectives as set out in the PAS and the National Recovery Plan:

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

With respect to the population of Macquarie perch within the Mid Murrumbidgee River, one relevant KTP is 'Introduction of fish to waters within a river catchment outside their natural range (FM Act)'.

The potential introduction of redfin perch into Tantangara Reservoir could potentially impact upon Macquarie perch present in the Mid-Murrumbidgee due to competition and predation pressures should redfin perch also establish downstream of the dam in the Mid-Murrumbidgee River and also associated with the potential threat of EHNV.

This risk is assessed as low to moderate.

Conclusion

The project has the potential to affect Macquarie perch populations known to occur in the Mid Murrumbidgee Catchment where the transfer of water (and Redfin perch) has a moderate residual risk. The project has the potential to transfer introduced fish and EHNV into this catchment which are known threats listed in the PAS and recovery plan for this species. Project-related activities are likely to constitute a KTP, although mitigation measures would help to reduce risks from this KTP and are consistent with the actions and objectives set out in the PAS and recovery plan for this species. No impacts on Macquarie perch from Snowy 2.0 are expected in the other catchments where it is known to occur.

1.2 Trout cod (*Maccullochella macquariensis*)

This species is listed as endangered under the FM Act.

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

The trout cod is endemic to the southern Murray-Darling river system, including the Murrumbidgee and Murray rivers, and the Macquarie River in central NSW. It was once widespread and abundant in these areas but has undergone dramatic declines in its distribution and abundance over the past century due to habitat loss and degradation, impacts from introduced species and historical illegal fishing. It prefers areas with instream woody debris and snags and it is often found in close proximity to cover in relatively fast flowing currents (NSW DPI 2017; McDowell 1996). It tends to be site-attached, and thus has a limited home range. The trout cod is a carnivorous top predator with a diet of crustaceans, aquatic insects and fish (NSW DPI 2017; McDowell, 1996). Its natural population is now limited to a single, self-sustaining population in the Murray River between Yarrawonga and Barmah (NSW DPI 2017). Its historic distribution included the Tumut River and Murrumbidgee River (NSW DPI 2006b; DSE 2008a) and its predicted distribution includes the Murrumbidgee River upstream to Cooma and the Murray River upstream of Lake Hume but not the Swampy Plain River, Tumut River and Yarrangobilly River Catchments (NSW DPI 2016a).

Within the study area, based on an extensive synthesis of literature and database reviews, results of eDNA surveys (EnviroDNA 2019 a, b) and field surveys for the Snowy 2.0 project, it has been deemed that trout cod occur within Talbingo Reservoir, within the Mid and Lower Murrumbidgee River Catchments and within the Murray River Catchment to Hume Reservoir. It also has a moderate likelihood of occurrence within the Upper Tumut River Catchment and the Yarrangobilly River based on its presence in an adjacent catchment (i.e. Talbingo Reservoir). All of these populations are considered to be derived from fish stocking. Of these populations, only the Talbingo Reservoir are considered to be potentially affected by the following project related activities:

> Construction of intakes and associated blasting and dredging works;
> In-reservoir placement of excavated material;
> Surface infrastructure and utilities;
> Transfer of water between Talbingo and Tantangara Reservoirs during operations; and
> Maintenance and decommissioning of infrastructure and utilities.

The construction of intakes and associated blasting and dredging works within Talbingo Reservoir would have the potential to cause a number of direct and indirect impacts to trout cod. These include the removal/modification of habitat, hydraulic entrainment from dredging operations, noise/vibration from blasting, changes to water quality and dredging related noise. These impacts were assessed in detail in **Section 6.2** of the main report. The residual risk from most of these impacting processes on trout cod have been assessed as low given the relatively small area that would be affected by these activities and the mobile nature of trout cod allowing them to avoid (to some extent) many of these impacts. The exception to this is for the impact of noise and vibration from blasting, which was assessed as a moderate risk to Trout cod within Talbingo Reservoir.

The edge placement of excavated material within Talbingo Reservoir could remove/modify trout cod habitat, displace/eradicate trout cod and indirectly impact these fish due to changes in water quality as a result of placement. These impacts have been assessed in detail in **Section 6.3** of the main report. In summary, the residual risks from these impacts on trout cod within Talbingo Reservoir have been assessed as low, with the exception of changes to water quality which would have a moderate risk level. Although it is possible that trout cod would temporarily experience indirect, sub-lethal effects due to high levels of turbidity, they would most likely move to areas within the reservoir or areas within feeder creeks and river arms with suitable habitat that are not subjected to high levels of turbidity. As trout cod are currently stocked into Talbingo Reservoir, any impacts on this species from construction related activities would be assuaged by the replenishment of individuals via the ongoing stocking of trout cod in this reservoir by DPI.

The construction of surface infrastructure and utilities (i.e. access roads, accommodation camps, construction compounds, subsurface utilities, power substations, ancillary construction facilities and wastewater outflows) could affect trout cod within Talbingo Reservoir and the Yarrangobilly River (see detailed impact assessment in **Section 6.4** of the main report) The cumulative effects of habitat removal and disturbance, diffuse surface water run-off and point source inputs of wastewater may impact on trout cod (and other species), although the residual risk from these impacts was assessed as low.

As trout cod are currently stocked into Talbingo Reservoir, any potential impacts on this species from construction related activities associated with Snowy 2.0 would be assuaged by the replenishment of individuals via the ongoing stocking of trout cod in this reservoir by DPI.

The transfer of water between Talbingo and Tantangara Reservoirs during operation of Snowy 2.0 is another potential pathway that could impact on trout cod within various catchments, including Talbingo Reservoir, the Yarrangobilly River and the Mid Murrumbidgee River Catchment. Impacting processes from the transfer of water (and where they have been assessed within the main report, **Section 8.2.2** to **Section 8.2.5**) include:

> Direct - Hydraulic entrainment and entrapment of biota (**Section 7.2.2**);
> Indirect - Impact of fish transfer on fish ecology (**Section 7.2.3**);
> Indirect - plant and phytoplankton transfer leading to HABs (**Section 7.2.4**); and
> Indirect - proliferation of non-native aquatic plants (**Section 7.2.4**).

The residual risks from each of these impacting processes were assessed as being either low to moderate for trout cod, with the transfer of redfin perch and associated fish disease transfer (within the Mid Murrumbidgee River Catchment), phytoplankton transfer (within Talbingo Reservoir) and the proliferation of non-native aquatic plants (within the Mid Murrumbidgee River Catchment) as being the processes with the highest risk (all moderate). Mitigation measures such as fish barrier controls and surveillance monitoring would be employed to help manage these risks throughout the duration of the project.

The maintenance and decommissioning of infrastructure and utilities have the potential to impact on trout cod within both Talbingo Reservoir and the Yarrangobilly River. Impacting processes from this activity include:

> Direct - removal/modification of aquatic habitat and associated biota;
> Indirect - changes to water quality due to tunnel dewatering (point source);

- Indirect - changes to water quality from diffuse surface run-off (diffuse); and
- Indirect – spread of aquatic weeds and pest fish.

A detailed impact assessment for the maintenance and decommissioning of infrastructure and utilities has been undertaken in **Section 7.3** of the main report. In summary, the residual risk to trout cod within both Talbingo Reservoir and the Yarrangobilly River was assessed as being low for all impacting process pathways listed above.

Based on the above assessments, project activities within these catchments would not be expected to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Table 1-4 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-5 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Trout cod**	Oc		Mod	Mod						Oc	Oc				Oc		
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

   i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

   ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

   i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

   ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

   iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-5**, the extent of impacts to trout cod habitat as per criteria d) i-iii are addressed and summarised in **Table 1-6** below.

Table 1-6 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the project

Criteria	Talbingo Reservoir	Yarrangobilly River Catchment	Mid Murrumbidgee River Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Some small areas of habitat are expected to be removed/modified due to placement of spoil and intake construction but it is not considered to be significant and is assessed as having a low residual risk to trout cod	Direct impacts to habitat important to trout cod are not expected to be significant and are assessed as having a low residual risk	Direct impacts to habitat important to trout cod are not expected to be significant and are assessed as a low residual risk	Potential impacts to trout cod are mostly associated with effects of water transfer between the two reservoirs and noise/vibration from blasting within Talbingo Reservoir and are not habitat related
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	Trout cod habitat within Talbingo Reservoir is not expected to become fragmented or isolated due to Snowy 2.0 construction or operations	Potential Trout cod habitat within the Yarrangobilly River Catchment is not expected to become fragmented or isolated due to Snowy 2.0 construction or operations	Trout cod habitat within the Mid Murrumbidgee River Catchment is not expected to become fragmented or isolated due to Snowy 2.0 construction or operations	Potential impacts to trout cod are mostly associated with effects of water transfer between the two reservoirs and noise/vibration from blasting within Talbingo Reservoir and are not habitat related
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	The small amount of habitat that would be affected as part of excavated material placement activities and intake construction is not considered important to the survival of the stocked population within Talbingo Reservoir	N/A	N/A	Very little habitat will be directly removed, modified or fragmented as part of Snowy 2.0 construction or operation. Ample suitable habitat in other parts of Talbingo Reservoir and feeder creeks would be available.

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the trout cod.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

A NSW recovery plan and a National recovery plan have been published for the trout cod.

https://www.dpi.nsw.gov.au/fishing/threatened-species/conservation/what/recovery/trout-cod-recovery-plan

http://www.environment.gov.au/biodiversity/threatened/recovery-plans/national-recovery-plan-trout-cod-maccullochella-macquariensis

The recovery objectives and actions within these documents in relation to trout cod mostly surround conservation works, research and monitoring, agency consultation and community engagement. Actions and objectives from these recovery plans that are related to the Snowy 2.0 project mostly include habitat maintenance/improvement, the protection/establishment of stocked populations and the minimisation of risks from introduced pest species. The construction and operation of Snowy 2.0 are unlikely to significantly interfere with these objectives.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

KTPs that could be facilitated by project activities are identified below.

> Degradation of native riparian vegetation along NSW water courses (FM Act);
> Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act) and alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands (BC Act);
> Introduction of fish to waters within a river catchment outside their natural range (FM Act); and
> Removal of large woody debris from New South Wales rivers and streams (FM Act).

The construction of surface infrastructure and utilities and the maintenance of and decommissioning of this infrastructure would involve the disturbance/clearing of some riparian vegetation along natural watercourses within the Yarrangobilly River Catchment. Some riparian vegetation along the foreshore of Talbingo Reservoir would also be disturbed during intake construction and in-reservoir excavated material placement. The disturbance of this riparian vegetation could lead to increased run-off and sediment loads into these waterbodies, and ultimately smothering potential trout cod habitat and displacing trout cod from these areas. Given that the area affected is small and appropriate sediment and erosion controls would be implemented during these works, the risk of this impacting on trout cod would be low.

The construction of a crossing in an unnamed first order watercourse draining into Talbingo Reservoir would involve the installation of an instream structure, although this would be below FSL within the reservoir. Instream structures have potential to alter flow regime and obstruct fish passage. Given the low likelihood of trout cod relying on this watercourse for refuge and habitat, the risk from the installation of instream structures is considered low and any impacts would be insignificant.

The construction of surface infrastructure and utilities, in particular intake construction and excavated material placement within Talbingo has the potential to affect large woody debris present within the disturbance area. Large woody debris is in high abundance within the reservoir as a result of the inundation of the river valley for reservoir creation. Based on aerial photography taken prior to inundation, the area proposed to affected, appears to contain relatively lower amounts than the remainder of the reservoir (see **Section 6.4**). The relative proportion woody debris within the reservoir to be affected is low. Thus, these works are unlikely to trigger or exacerbate this KTP in relation to trout cod.

The potential introduction of redfin perch into Tantangara Reservoir could potentially impact upon Trout Cod present in the Mid Murrumbidgee River Catchment due to competition and predation pressures should redfin perch firstly established in the reservoir and then also establish downstream of the Tantangara dam wall. The potential risk of EHNV transfer is not considered relevant for trout cod as they have been shown to be resistant to infection with EHNV (Hick et al. 2019). This residual risk is assessed as moderate.

Conclusion

The project has the potential to directly affect the stocked trout cod population known to occur in Talbingo Reservoir through a number of impacting processes, which have been assessed as having a moderate residual risk to trout cod. The project has the potential to transfer introduced fish across catchments to the population of trout cod in the Mid Murrumbidgee River catchment, which is a known threat listed in the recovery plans for this species. Some project related activities are likely to constitute KTPs, although the following mitigation measures would help to alleviate the risks from these and are consistent with the actions and objectives set out in the recovery plans for this species:

***AE01**: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat*

***AE22**: Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel*

1.3 River blackfish – Snowy River Catchment Population (*Gadopsis marmoratus*)

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable (endangered population, see item b) below

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

The Snowy River population of river blackfish is listed as an endangered population under the FM Act. River blackfish were once abundant in the Snowy River Catchment but are now found only along about 50 km of waterways of the Delegate River and some of its tributaries (NSW DPI, 2014). The Delegate River is a tributary of the Snowy River located outside of the Snowy Water Catchment below Jindabyne Dam.

The predicted distribution in the Snowy River Catchment includes the Delegate River and its tributaries where it is known to occur, as well as the Eucumbene River between Eucumbene dam wall and Lake Jindabyne, and the lower Thredbo River and lower Mowamba River (DPI, 2016) (i.e. the Lake Jindabyne catchment of the study area) where there are no known records of the species. Below Guthega, the Island Bend and Jindabyne dams and the Eucumbene River below Eucumbene Dam are regulated by the Snowy Scheme and as a result these sections of river are unlikely to provide suitable habitat for this species.

No direct impacts associated with construction of Snowy 2.0 are expected to occur in any areas where this species is known or modelled to occur. There is also no potential for any aspect of the project to affect the known population of Snowy River Blackfish occurring in the Delegate River. The transfer of water between Talbingo and Tantangara Reservoirs during operation of Snowy 2.0 is a potential impact pathway if any of these fish are present in the Jindabyne catchment although no impact is expected following the installation of a fish barrier that would prevent fish transfer to Lake Eucumbene via the Murrumbidgee-Eucumbene (M-E) Tunnel.

Table 1-7 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-8 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**River blackfish (Snowy River Population)**						Oc									Oc		
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-8**, the extent of impacts to river blackfish habitat as per criteria d) i-iii are addressed and summarised in **Table 1-9** below.

Table 1-9 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Lower Tumut Catchment	Murray River to Hume Reservoir Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Direct impacts to habitat important to the Snowy River Catchment population of river blackfish are not expected	Direct impacts to habitat important to the Snowy River Catchment population of river blackfish are not expected	Project activities are not expected to overlap with habitat of this species
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to the Snowy River Catchment population of river blackfish are expected to result in the fragmentation or isolation of habitat	No direct impacts to habitat important to the Snowy River Catchment population of river blackfish are expected to result in the fragmentation or isolation of habitat	Project activities are not expected to overlap with habitat of this species
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	N/A	No habitat will be directly removed, modified or fragmented

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the river blackfish.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan threat abatement plan (or Priority Action Statement).***

Although there is a PAS for the Snowy River Catchment population of river blackfish, the project is not expected to impact this population or habitats within this catchment. As such, impacts associated with project activities would not be inconsistent with recovery actions of the PAS.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

KTPs that could be facilitated by project activities are identified below.

> Introduction of fish to waters within a river catchment outside their natural range (FM Act).

The potential introduction of non-native fish into the Snowy River via the M-E Tunnel could potentially impact upon river blackfish in this catchment due to additional competition and predation pressures, although mitigation measures such as fish barrier controls would mitigate this impact. As such, the residual risk to the Snowy River Catchment population of river blackfish from the introduction of redfin perch would be moderate (see **Section 7.2.3.7**)

Conclusion

The project is not expected to significantly impact the Snowy River Catchment population of river blackfish as the extent of impacts from project activities would not overlap or impact on the catchments in which the river blackfish is known to occur. Direct or indirect impacts to this species / population as a result of Snowy 2.0 are not, therefore expected and would not adversely affect the life cycle or habitat of the species. The project is not inconsistent with any recovery plan and, although may potentially facilitate a KTP in the catchments where the species occurs via the introduction of non-native fish to this catchment, fish barrier controls would mitigate this risk.

1.4 Southern pygmy perch (*Nannoperca australis*)

This species is listed as endangered under the FM Act.

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

Based on information provided from existing literature, field studies and eDNA testing, the distribution of the southern pygmy perch (within the study area) is known to occur in the Murray River to Hume Reservoir and Lower Snowy River Catchments and has a moderate likelihood of occurrence in the Mid-Murrumbidgee River Catchment. Its predicted distribution within the Mid Murrumbidgee River includes the Numeralla River (DPI, 2016), although it was not caught there during limited surveys undertaken by NSW DPI and there are no known records of its occurrence there. Of these populations, only the Mid-Murrumbidgee population is discussed here as no risks to the other populations in the Murray River and the Lower Snowy River have been identified. For the purpose of this assessment it has been assumed that the southern pygmy perch present within the study area constitute a wild, self-sustaining population, although there is no evidence that this species has been detected in this location. Further information is provided in **Section 4.1.5**. of **Annexure B**.

No direct impacts associated with construction of Snowy 2.0 are expected to occur in any areas where this species is known or modelled to occur. Once Snowy 2.0 is operational, water transfers between Talbingo Reservoir and Tantangara Reservoir have the potential to transfer invasive fish species (redfin perch, gambusia and climbing galaxias) from Talbingo to Tantangara. If in the case of redfin perch and climbing galaxias (which are not considered present in the Mid-Murrumbidgee River), if these species establish in Tantangara Reservoir and are subsequently able to be transferred and establish in the Mid-Murrumbidgee River catchment, and are able to migrate upstream into the Numerala River, there is potential for them to impact on the population of southern pygmy perch that may be present in via predation and competition (**Table 1-10** and **Table 1-11**). The likelihood of this is considered to be Rare following the proposed installation of a barrier to prevent the transfer of all life stages of fish through Tantangara dam wall. The likelihood of transfer via spills from Tantangara Reservoir is also considered rare due to the high capacity for Snowy Hydro to be able to manage inflows into this reservoir and prevent spill following completion of Snowy 2.0. Risks associated with EHNV are not considered relevant to southern pygmy perch as it has been shown in experimental testing to be resistant to the disease. Further detail around these processes is provided in **Section 7.2** of the main report.

The following mitigation measures relevant to protecting pygmy perch will be implemented:

AE01: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat;

AE18: Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel; and

AE19: The surveillance and management of HAB will be in accordance with existing Snowy Hydro procedures.

The residual impacts of water transfer on southern pygmy perch potentially occurring in the Mid Murrumbidgee River Catchment would be low to moderate and are not be expected to have an adverse effect on the life cycle of the southern pygmy perch such that a viable local population of the species is likely to be placed at risk of extinction.

Table 1-10 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-11 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Southern pygmy perch**										Mod				Oc	Oc		
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

   i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

   ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

   i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

   ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

   iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-11**, the extent of impacts to southern pygmy perch habitat as per criteria d) i-iii are addressed and summarised in **Table 1-12** below.

Table 1-12 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Mid Murrumbidgee River	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	No direct impacts to habitat important to southern pygmy perch are expected	Impacts are associated with indirect effects of water transfer between Talbingo and Tantangara reservoirs
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to southern pygmy perch are expected to result in the fragmentation or isolation of habitat	Impacts are associated with indirect effects of water transfer between Talbingo and Tantangara reservoirs
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	No habitat will be directly removed, modified or fragmented

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the southern pygmy perch.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

A Priorities Action Statement exists for the southern pygmy perch:

https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/endangered-species/southern-pygmy-perch/priorities-action-statement-actions-for-southern-pygmy-perch

The recovery objectives and actions of the PAS mostly relate to conservation works, research and monitoring, agency consultation and community engagement. Objectives that directly relate to Snowy 2.0 include objectives for habitat rehabilitation and pest eradication/control, particularly to take action to prevent the spread of introduced species into the habitat of southern pygmy perch.

All of the mitigation actions to minimise the risk and monitor for pests and diseases would be consistent with the recovery actions of the PAS.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

Project activities as relevant to southern pygmy perch could facilitate the KTP: 'introduction of fish to waters within a river catchment outside their natural range'.

As discussed in item a) a number of mitigation and management measures would be implemented to address this KTP.

Conclusion

Provided that the mitigation measures outlined in item a) are implemented then the project is not expected to significantly impact southern pygmy perch or their habitat within the Mid Murrumbidgee Catchment. Operation of Snowy 2.0 is not, therefore expected to significantly affect the life cycle of the species such that a viable local population of the species is placed at risk of extinction. The project mitigation measures are consistent with the species PAS and measures would be in place to minimise the potential for a KTP to be facilitated.

1.5 Silver perch (*Bidyanus bidyanus*).

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

This species is listed as vulnerable under the FM Act. Silver perch are known to occur within the Lower-Murrumbidgee River and Blowering Reservoir Catchments and have a moderate likelihood of occurrence in the Lower Tumut River Catchment of the study area (**Table 1-13** and **Table 1-14**). The Blowering Reservoir population is likely to be stocked and therefore not self-sustaining. This distribution is based on information provided from existing literature, field studies and eDNA testing. As indicated in **Table 1-14** the extent of impacts from project activities is not, however, expected to overlap or impact on any of the catchments where silver perch are known to occur within the study area. Direct or indirect impacts to this species as a result of Snowy 2.0 are not, therefore expected to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Table 1-13 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-14 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Silver perch**					Oc	Mod					Oc						
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

   i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

   ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

   i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

   ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

   iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-14**, the extent of impacts to silver perch habitat as per criteria d) i-iii are addressed and summarised in **Table 1-15** below.

Table 1-15 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Lower-Murrumbidgee River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Direct impacts to habitat important to silver perch are not expected	Direct impacts to habitat important to silver perch are not expected	Direct impacts to habitat important to silver perch are not expected	Project activities are not expected to overlap with habitat of this species
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to silver perch are expected to result in the fragmentation or isolation of habitat	No direct impacts to habitat important to silver perch are expected to result in the fragmentation or isolation of habitat	No direct impacts to habitat important to silver perch are expected to result in the fragmentation or isolation of habitat	Project activities are not expected to overlap with habitat of this species
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	N/A	N/A	No habitat will be directly removed, modified or fragmented

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the silver perch.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

Although there is a recovery plan for the silver perch, the project is not expected to impact the species or habitats within the Lower Tumut, Blowering or Lower Murrumbidgee Catchments where they are known to or potentially occur. As such, impacts associated with project activities would not be inconsistent with the recovery plan.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

There are no KTPs that would be facilitated or exacerbated by project activities within the known distribution of silver perch as there would be no overlap of project activities with the species known distribution within the study area.

Conclusion

The project is not expected to significantly impact silver perch as the extent of impacts from project activities would not overlap or impact on the catchments in which silver perch is known or has potential to occur. Direct or indirect impacts to this species as a result of Snowy 2.0 are not, therefore expected and would not adversely affect the life cycle or habitat of the species. The project is not inconsistent with any recovery plan and would not facilitate a KTP in the catchments where the species occurs.

1.6 Stocky galaxias (*Galaxias tantangara*)

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

The stocky galaxias is listed as critically endangered under the FM Act. It is a newly described species that is part of the mountain galaxias (*Galaxias olidus*) complex. It has an extremely limited distribution within a reach of approximately 3 km of Tantangara Creek above a waterfall (i.e. Upper Tantangara Creek) which is thought to exclude predatory trout present downstream (Lintermans, 2018). This distribution is based on information provided from existing literature. Their habitat consists of a small, cold, fast-flowing alpine creek with clear water flowing through open forest of eucalypts, low shrubs and tussock grasses (NSW DPI 2018). The creek above the waterfall generally consists of riffle and glide habitat. Further information is provided in **Annexure B** (**Section 4.1.7**). The section of creek in which the stocky galaxias is known to occur is delineated as the Upper Tantangara Creek Catchment. Project activities that have potential to impact on the Upper Tantangara Creek Catchment include the construction of surface infrastructure and utilities, the transfer of water between Talbingo and Tantangara reservoirs and the maintenance and decommissioning of infrastructure and utilities (**Table 1-16** and **Table 1-17**). The potential impacts associated with these activities are discussed below:

> Construction of surface infrastructure and utilities

The construction of surface infrastructure will involve subsurface utilities (communications) transecting Tantangara Creek, Boggy Plain Creek (a tributary of Tantangara Creek) and several unnamed tributaries of these creeks. Construction at these locations would occur in a manner that will not obstruct flow and would minimise habitat disturbance (e.g. by underboring) to minimise disturbance to stream flow and fish passage especially in type 1 and 2 fish habitat (DPI 2013). Areas where subsurface utilities cross Tantangara Creek would be downstream of the waterfall which isolates the stocky galaxias population and where impacts upstream of this would not occur. Further, to prevent the potential movement of climbing galaxias into the Upper Tantangara Creek Catchment, a specially designed fish barrier is proposed in Tantangara Creek just upstream of the waterfall upstream of Alpine Creek Trail. This barrier is designed to prevent movement of climbing galaxias into the upstream 4 km of Tantangara Creek above the waterfall where it may impact stocky galaxias. The use of heavy plant and equipment during construction may act as a vector for pest species (such as elodea or redfin perch eggs) that may spread across catchments, however, this would be managed as outlined in a Weed, Pest and Pathogen Management Plan. All mitigation measures to minimise risks associated with utilities crossings of Tantangara Creek on stocky galaxias would include:

AE20: Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure decommissioning to manage impacts of diffuse surface run-off on receiving watercourses. Ongoing road maintenance will be managed in accordance with existing Snowy Hydro procedures

AE11: Rehabilitation of temporary roads would occur in accordance with the Rehabilitation Plan;

AE02: Bridges or culverts would be designed and constructed in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge, 2003) where feasible;

AE03: Construction works within the channel of a permanent waterway containing type 1 or 2 key fish habitat would allow sufficient flow to maintain fish passage at all times and be staged to minimise the total disturbance at any given time;

AE12: Where possible, an exclusion buffer will be applied for road construction either side of a river except where bridges or other crossing structures are required

AE13: Procedures for the management of woody debris disturbed during construction of bridges or other waterway crossings would be outlined within the AqHMP;

AE14: Where cable routes intersect permanent waterways containing type 1 or 2 key fish habitat, construction will be carried out in a manner that does not obstruct flow and minimises habitat disturbance;

AE15: Wastewater, including tunnel process water, will be treated and released in accordance with the measures specified in the Water Management Plan;

AE16: Wastewater outlets would be designed and positioned to minimise the footprint of hard bank engineering and prevent bank scouring and erosion; and

AE04: A Weed, Pest and Pathogen Management Plan will be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens.

> Transfer of water between Talbingo and Tantangara Reservoirs

During the commissioning and operational phase of Snowy 2.0 water transfers between Talbingo and Tantangara reservoirs would occur. These water transfers have the potential to facilitate movement of fish into Tantangara Reservoir. An impact to stocky galaxias would only be expected to occur if they are able to penetrate into the Upper Tantangara catchment. Presently, the natural waterfall barrier on Tantangara Creek has prevented trout interacting with stocky galaxias and it is expected that redfin perch would also be unable to navigate the waterfall barrier. In the event that climbing galaxias are transferred and established in Tantangara Reservoir, it is possible that these fish may be able to migrate above the existing waterfall barrier where they may compete with stocky galaxias. To prevent this, a fish barrier would be constructed at a location immediately above the waterfall to prevent climbing galaxias from moving into stocky galaxias habitat. It is not known whether stocky galaxias are susceptible to EHNV, but the consequence is considered potentially catastrophic for the species if infected transferred fish were to enter this habitat, given its extremely limited distribution. Mitigation using a barrier to prevent movement of climbing galaxias reduces the risk to moderate for stocky galaxias, although the likelihood of an impact to stocky galaxias from fish transfer is considered rare.

A monitoring program would also be designed and implemented to monitor the distribution of pest fish in key locations within the project area. The details will be set out in a Pest Fish Monitoring Plan.

> Maintenance and decommissioning of infrastructure and utilities

Maintenance and decommissioning works over the broader plateau region including Tantangara Creek will largely be downstream of the waterfall separating the stocky galaxias population from areas of infrastructure and maintenance and therefore any indirect impacts from the translocation of pest species via plant and equipment are not predicted. All maintenance activities would be undertaken in accordance with standard Snowy Hydro Procedures including measures to prevent the spread of weeds, pests and pathogens.

With the mitigation measures outlined above in place, the residual risks to the stocky galaxias in the Upper Tantangara Catchment are low to moderate and adverse effects on stocky galaxias to the extent that its local occurrence or composition is placed at risk of extinction are not predicted.

Table 1-16 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-17 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Stocky galaxias**									Oc								
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

   i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

   ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

   i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

   ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

   iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-17**, the extent of impacts to stocky galaxias habitat as per criteria d) i-iii are addressed and summarised in **Table 1-18** below.

Table 1-18 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Upper Tantangara Creek	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	No significant impacts to habitat important to stocky galaxias are expected	Only a very small portion of stocky galaxias habitat upstream of the waterfall barrier would be affected as a result of the fish barrier construction
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to stocky galaxias are expected to result in the fragmentation or isolation of habitat	As above
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	As above

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the stocky galaxias.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

A Priorities Action Statement exists for the stocky galaxias:

https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/endangered/snowy-river/priorities-action-statement-actions-for-snowy-river-aquatic-endangered-ecological-community

The recovery objectives and actions of the PAS mostly relate to conservation works, research and monitoring, agency consultation and community engagement. Impacts from Snowy 2.0 that are related to these objectives and actions mostly include habitat protection, habitat rehabilitation and pest eradication/control. Specific habitat protection actions that are relevant to the project include:

> Protect and restore riparian habitat in Tantangara Creek which supports the only known habitat for stocky galaxias (High priority); and

> Ensure stocky galaxias conservation requirements are included in fishway programs (Medium priority).

All of the mitigation actions to minimise disturbance would be consistent with the recovery actions of the PAS. The fish barrier above the waterfall on Tantangara Creek to prevent the potential incursion of invasive fish into this catchment is consistent with the objective to protect and restore habitat of this species. The barrier would also be expected to act as secondary defence, in addition to the waterfall, that would continue to keep other fish species such as trout, that are already present downstream, outside of this habitat.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

KTPs that could be facilitated by project activities are identified below.

> Degradation of native riparian vegetation along NSW water courses (FM Act);

> Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act) and alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands (BC Act);

> Introduction of fish to waters within a river catchment outside their natural range (FM Act);

As discussed in item a) a number of mitigation and management measures would be implemented to address each of the KTPs listed above.

Conclusion

Provided that the mitigation measures outlined in item a) are implemented then the project is not expected to significantly impact stocky galaxias *or their habitat that occur in the Upper Tantangara Creek Catchment. Construction and / or operation of Snowy 2.0 is not, therefore expected to significantly affect the life cycle of the species such that a viable local population of the species is placed at risk of extinction. The project is not inconsistent with a PAS and measures would be in place to minimise the potential for a KTP to be facilitated.*

1.7 Murray-Darling basin population of eel tailed catfish (*Tandanus tandanus*)

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable (endangered population, see item b) below

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

This population is listed as endangered under the FM Act.

Eel tailed catfish constituting the Murray-Darling population are known to occur within the Lower Murrumbidgee Catchment (**Table 1-19** and **Table 1-20**) of the study area. This distribution is based on information provided from existing literature, field studies and eDNA testing. As indicated in **Table 1-20**, Snowy 2.0 is not expected to have any impacts, either direct or indirect, on this catchment. Direct or indirect impacts to this population as a result of Snowy 2.0 are not, therefore expected to have an adverse effect on the life cycle of the species that constitutes the Murray-Darling population.

Table 1-19 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Occs	= Potential species / impact interaction – Occurs

X	= Project activity with potential to impact on catchment

Table 1-20 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Eel tailed catfish (Murray-Darling Population)**											Oc						
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

  i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

  ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

  i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

  ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

  iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-20**, the extent of impacts to the Murray Darling population of eel-tailed catfish habitat as per criteria d) i-iii are addressed and summarised in **Table 1-21** below.

Table 1-21 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the project

Criteria	Lower Tumut Catchment	Murray River to Hume Reservoir Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Direct impacts to habitat important to eel tailed catfish (Murray-Darling population) are not expected	Direct impacts to habitat important to eel tailed catfish (Murray-Darling population) are not expected	Project activities are not expected to overlap with habitat of this species
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to eel tailed catfish (Murray-Darling population) are expected to result in the fragmentation or isolation of habitat	No direct impacts to habitat important to eel tailed catfish (Murray-Darling population) are expected to result in the fragmentation or isolation of habitat	Project activities are not expected to overlap with habitat of this species
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	N/A	No habitat will be directly removed, modified or fragmented

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the Murray Darling population of eel-tailed catfish.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan threat abatement plan (or Priority Action Statement)***

Although there is a Priority Action Statement (PAS) for the Murray-Darling population of eel-tailed catfish, the project is not expected to impact the species or habitats within the Lower Murrumbidgee Catchment where they are known to occur. As such, impacts associated with project activities would not be inconsistent with recovery actions of the PAS.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

There are no KTPs that could be facilitated or exacerbated by project activities within the known distribution of the Murray Darling population of eel-tailed catfish.

Conclusion

The project is not expected to significantly impact the Murray-Darling Basin population of eel-tailed catfish as the extent of impacts from project activities would not overlap or impact on the Lower Murrumbidgee Catchment in which the eel tailed catfish is known to occur. Direct or indirect impacts to this species as a result of Snowy 2.0 are not, therefore expected and would not adversely affect the life cycle or habitat of the species and population. The project is not inconsistent with the population PAS and would not facilitate a KTP in the catchments where the species occurs.

1.8 Alpine redspot dragonfly (*Austropetalia tonyana*)

This species is listed as vulnerable under the FM Act

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

The alpine redspot dragonfly is known to occur within the Swampy Plain River Catchment and has a moderate likelihood of occurrence in the Lake Jindabyne and Geehi and M2 Reservoir catchments (**Table 1-22** and **Table 1-23**) of the study area. This distribution is based on information provided from existing literature. As indicated in **Table 1-23**, the extent of impacts from project activities are not, however, expected to overlap or impact on these catchments. Direct or indirect impacts to this species as a result of Snowy 2.0 are not, therefore expected to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Table 1-22 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Occs	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-23 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Alpine redspot dragonfly**													Mod			Oc	Mod
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-23**, the extent of impacts to alpine redspot dragonfly habitat as per criteria d) i-iii are addressed and summarised in **Table 1-24** below.

Table 1-24 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the project

Criteria	Lower Tumut Catchment	Murray River to Hume Reservoir Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Direct impacts to habitat important to alpine redspot dragonfly are not expected	Direct impacts to habitat important to alpine redspot dragonfly are not expected	Project activities are not expected to overlap with habitat of this species
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	No direct impacts to habitat important to alpine redspot dragonfly are expected to result in the fragmentation or isolation of habitat	No direct impacts to habitat important to alpine redspot dragonfly are expected to result in the fragmentation or isolation of habitat	Project activities are not expected to overlap with habitat of this species
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	N/A	N/A	No habitat will be directly removed, modified or fragmented

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the alpine redspot dragonfly.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

There is no existing recovery plan or threat abatement plan applicable to the alpine redspot dragonfly.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

There are no KTPs that could be facilitated or exacerbated by project activities within the known distribution of the alpine redspot dragonfly as there would be no overlap of project activities with the species known distribution within the study area.

Conclusion

The project is not expected to significantly impact the alpine redspot dragonfly as the extent of impacts from project activities would not overlap or impact on the catchments in which the dragonfly is known or has potential to occur. Direct or indirect impacts to this species as a result of Snowy 2.0 are not, therefore expected and would not adversely affect the life cycle or habitat of the species. The project is not inconsistent with any recovery plan and would not facilitate a KTP in the catchments where the species occurs.

1.9 Murray crayfish (*Euastacus armatus*)

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

The Murray crayfish is listed as vulnerable under the FM Act. They are endemic to the Murray-Darling Basin, including the Murrumbidgee River and many of its tributaries (NSW DPI 2019). The Murray crayfish population has suffered a significant decline over the last 50 years, with severe flooding, river regulation and various land practices causing high mortality and slow recovery (Lintermans 2019; NSW DPI, 2019). They prefer cool, well oxygenated, flowing water and are found in a range of environments, such as pasture-lands to sclerophyll forest. They tend to be most active in the cooler months between May and October (NSW DPI 2019). They are long-lived and slow-growing, with females and males taking up to ten and four years to reach sexual maturity, respectively, and can live for up to 28 years. Murray crayfish are opportunistic feeders, with a wide dietary range and are able to feed on decaying aquatic plant matter, dead fish and other animals. Cannibalism has also been reported within high-density populations (NSW DPI, 2019).

Within the study area, based on an extensive synthesis of literature and database reviews, results of eDNA surveys (EnviroDNA 2019 a, b) and field surveys for the Snowy 2.0 project, it has been deemed that Murray crayfish occur within the following catchments:

> Talbingo Reservoir;
> T2 Reservoir Catchment;
> Yarrangobilly River Catchment;
> Blowering Reservoir;
> Lower Tumut River Catchment;
> Mid Murrumbidgee River Catchment;
> Lower Murrumbidgee River Catchment;
> Murray River Catchment to Hume Reservoir; and
> Swampy Plain River Catchment.

They also have a moderate likelihood of occurrence within the Upper Tumut River Catchment. Based on information presented in **Table 1-25** and **Table 1-26**, project related activities that have the potential to affect this species within these catchments include:

> Construction of intakes and dredging works;
> In-reservoir edge placement of excavated material;
> Surface infrastructure and utilities;
> Transfer of water between Talbingo and Tantangara reservoirs; and
> Maintenance and decommissioning of infrastructure and utilities.

The construction of intakes and any associated blasting and dredging works within Talbingo Reservoir may cause direct and indirect impacts to Murray crayfish there. Potential impacts include the removal/modification of habitat, hydraulic entrainment from dredging operations, noise/vibration from blasting, changes to water quality and dredging and blasting related noise. These impacts were assessed in detail (**Section 7.2** of the main report). In summary, the residual risks from these impacting processes on Murray crayfish were assessed as low and are not considered to be significant given the relatively small area that would be affected by these activities.

The subaqueous edge placement of spoil material within Talbingo Reservoir has the potential to remove/modify Murray crayfish habitat, displace/eradicate Murray crayfish within the immediate area and indirectly impact these invertebrates due to changes in water quality as a result of spoil placement (see detailed assessment in **Section 7.3** of the main report). The residual risks from most of these potential impacts on Murray crayfish within Talbingo Reservoir have been assessed as low, with the exception of changes to water quality which would have a moderate risk level. The assessment of a moderate risk was due to the potential for the smothering of habitat from the deposition of suspended sediments resulting from spoil placement. This impact is likely to be reservoir-wide, although a translocation program would be undertaken with the work area prior to excavated material placement activities to remove as many Murray crayfish as possible from areas that will be directly disturbed. Therefore, it is considered that the risk to Murray crayfish is manageable based on the mitigation measures put forward.

The construction of surface infrastructure and utilities could impact on Murray crayfish within Talbingo Reservoir and the Yarrangobilly River (see detailed impact assessment in **Section 7.4** of the main report). In summary, the cumulative effects of habitat removal and disturbance, impediment to movement of fish and macroinvertebrates, diffuse surface water run-off and point source inputs of wastewater have potential to impact on Murray crayfish, although the residual risk from these impacts was assessed as low, given that appropriate road design, sediment and erosion controls, and best practice crossing design and construction would be undertaken.

The transfer of water between Talbingo and Tantangara reservoirs is another potential pathway that could impact on Murray crayfish within various catchments, including Talbingo Reservoir, the Yarrangobilly River and the Mid Murrumbidgee River Catchment. Impacting processes from the transfer of water (and where they have been assessed within the report) include:

> Direct - Hydraulic entrainment and entrapment of biota (Talbingo population only; **Section 7.2.2**);
> Indirect - Impact of fish transfer on fish ecology (Mid-Murrumbidgee Population only; **Section 7.2.3**);
> Indirect - plant and phytoplankton transfer leading to HABs;
> Indirect - proliferation of non-native aquatic plants; and

The potential for Murray crayfish to be entrained with the Snowy 2.0 intake and be lost from the population is considered unlikely and it is not expected that this would occur in sufficient numbers to affect the overall population present within the reservoir. The potential impact on Murray crayfish from fish transfer into the Mid Murrumbidgee catchment is expected to be prevented via the secondary controls to be installed at Tantangara Dam which are expected to prevent the migration of all fish downstream of the dam.

In summary, the residual risks from each of these impacting processes were assessed as being either low to moderate for Murray crayfish, with the transfer of redfin perch/gambusia and associated predation (within the Mid Murrumbidgee River Catchment and Swampy Plain River Catchment), phytoplankton transfer (within Talbingo Reservoir) and the proliferation of non-native aquatic plants (within the Mid Murrumbidgee River Catchment) as being the processes with the highest risk to this species (all moderate risk). Mitigation measures such as fish barrier controls and surveillance monitoring would be employed to help manage these risks throughout the duration of the project.

The maintenance and decommissioning of infrastructure and utilities have the potential to impact on Murray crayfish within Talbingo Reservoir and the Yarrangobilly River Catchment. Impacting processes from this activity include:

> Direct - removal/modification of habitat and associated biota;
> Indirect - changes to water quality due to tunnel dewatering (point source);
> Indirect - changes to water quality from diffuse surface run-off (diffuse); and
> Indirect – spread of aquatic weeds and pest fish.

A detailed impact assessment for the maintenance and decommissioning of infrastructure and utilities has been undertaken in **Section 7.3** of the main report. In summary, the residual risks to Murray crayfish within both Talbingo Reservoir and the Yarrangobilly River Catchment were assessed as being low for all impacting process pathways listed above.

Based on the above assessments, project activities within these catchments would not be expected to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction provided the appropriate controls are put in place to manage risk to Murray crayfish.

Table 1-25 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-26 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Murray crayfish**	Oc	Oc	Mod	Oc	Oc	Oc				Oc	Oc				Oc	Oc	
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)	X																

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect - proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality							X	X	X			X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

Not applicable.

d. ***In relation to the habitat of a threatened species, population or ecological community:***

i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.

Based on the impacts and locations identified in **Table 1-26**, the extent of impacts to Murray crayfish habitat as per criteria d) i-iii are addressed and summarised in **Table 1-27** below.

Table 1-27 Table C-2. Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Talbingo Reservoir	Yarrangobilly River Catchment	Mid Murrumbidgee River Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Some small areas of habitat are expected to be removed/modified due to subaqueous edge placement of spoil but it is not considered to be significant and is assessed as having a low residual risk to Murray crayfish. Some habitat would also be smothered via deposition of suspended sediments from spoil placement activities	Direct impacts to habitat important to Murray crayfish are not expected to be significant and are assessed as having a low residual risk	Impacts to habitat important to Murray crayfish have moderate residual risk (proliferation of non-native aquatic plants) (i.e. *Elodea*)	There is some risk (assessed as moderate) to the extent of Murray crayfish habitat being removed or modified as part of the Snowy 2.0 works and this occurs across a number of catchments (Talbingo Reservoir and Mid Murrumbidgee River Catchment)
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	Murray crayfish habitat within Talbingo Reservoir is not expected to become significantly fragmented or isolated due to Snowy 2.0 construction or operations	Murray crayfish habitat within the Yarrangobilly River Catchment is not expected to become significantly fragmented or isolated due to Snowy 2.0 construction or operations	Murray crayfish habitat within the Mid Murrumbidgee River Catchment is not expected to become significantly fragmented or isolated due to Snowy 2.0 construction or operations	Although there is some risk that Murray crayfish habitat would be removed or modified (see above), fragmentation or isolation of this habitat is not considered to be significant
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	The moderate risk that habitat would be removed /modified is considered to be manageable provided various environmental management plans and control measures are implemented to control this risk	N/A	The moderate risk that habitat would be removed /modified is considered to be manageable provided various environmental management plans and control measures are implemented to control this risk N/A	It is considered that the importance of any habitat removed/modified as part of Snowy 2.0 would not threaten the long-term survival of the Murray crayfish populations within these catchments if managed with the appropriate mitigation

				measures outlined in the assessment

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the Murray crayfish.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

No recovery plans have been developed for the Murray crayfish. However, the following Priority Action Statements for Murray crayfish (NSW DPI, 2018b) exist

https://www.dpi.nsw.gov.au/fishing/species-protection/what-current/vulnerable-species/murray-crayfish/priorities-action-statement-actions-for-murray-crayfish

The recovery actions within this document in relation to Murray crayfish mostly surround conservation works, research and monitoring, agency consultation and community engagement. Actions that are related to the Snowy 2.0 project mostly include habitat rehabilitation, pest eradication and control, research/monitoring and stocking/translocation. The construction and operation of Snowy 2.0 are unlikely to interfere significantly with these actions and mitigation measures would be consistent with outcomes from the PAS.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

KTPs that could be facilitated by project activities are identified below.

- Degradation of native riparian vegetation along NSW water courses (FM Act);
- Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act) and alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands (BC Act);
- Introduction of fish to waters within a river catchment outside their natural range (FM Act); and
- Removal of large woody debris from New South Wales rivers and streams (FM Act);

The most relevant KTP listed above in relation to Murray crayfish would be the removal of large woody debris from various areas within the study area, such as Talbingo Reservoir and within the Yarrangobilly River Catchment. As large woody debris is sometimes used as cover for when burrowing, any removal of this debris may impact on Murray crayfish within these catchments. Given the control measures to replace any woody debris removed as a result of construction activities, the impacts of this KTP on Murray crayfish would be minimal.

Activities such as the construction of surface infrastructure and utilities and the maintenance of and decommissioning of this infrastructure would involve the disturbance/clearing of some riparian vegetation along natural watercourses within the Yarrangobilly River Catchment. Some riparian vegetation along the foreshore of Talbingo Reservoir would also be disturbed during subaqueous placement of spoil. The disturbance of this riparian vegetation could lead to increased run-off and sediment loads into these waterbodies, and ultimately smothering potential Murray crayfish habitat and displacing Murray crayfish from these areas. Given that appropriate sediment and erosion controls would be implemented during these works, the risk from this impacting on Murray crayfish would be low.

Conclusion

The Project has the potential to affect Murray crayfish populations known to occur in Talbingo Reservoir and the Mid Murrumbidgee River Catchment through a number of impacting processes, of which have been assessed as having a moderate residual risk to Murray crayfish. The project has the potential to remove/modify crayfish habitat and transfer introduced fish (and increase predation / competition risks) across catchments which are known threats to this species. Some project related activities are likely to constitute KTPs, although mitigation measures would help to alleviate any risks from these and are consistent with the actions and objectives set out in the recovery plans for this species.

1.10 Snowy River Endangered Ecological Community

a. ***In the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

b. ***In the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.***

Not applicable.

c. ***In the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:***

   i. ***is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***

   ii. ***is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.***

The aquatic ecological community of the Snowy River Catchment in NSW has been listed as an endangered ecological community (EEC) under the FM Act. The listing includes all native fish and aquatic invertebrates within all rivers, creeks and streams within the EEC including the Snowy, Eucumbene, Thredbo, Gungarlin, Mowamba, Bombala, McLaughlin, Delegate, Pinch and Jacobs Rivers. It includes the riverbed channels inundated by the artificial impoundments of Jindabyne, Eucumbene, Island Bend and Guthega dams, but excludes the ecological communities that have developed in the waters of these impoundments. Subject to the special arrangements applying to recreational fishing, the listing of the EEC in the catchment of the Snowy River in NSW has given all native fish and other aquatic invertebrates within its boundaries the status of endangered species (DPI, 2012).

The catchments within the study area that include part of the Snowy River EEC are Lake Jindabyne, Lake Eucumbene, Lower Snowy River and the Murray River to Hume Reservoir catchments. Of these, only the Lake Eucumbene Catchment has potential to be affected by project activities (**Table 1-28** and **Table 1-29**). This potentially includes direct impacts to habitat during the construction of surface infrastructure and utilities and the transfer of water between Talbingo and Tantangara reservoirs during operation, noting that the Lake Eucumbene Catchment is linked to Tantangara Reservoir via the unidirectional Murrumbidgee-Tantangara Portal (thus there is a connection to the Snowy River EEC). The maintenance and decommissioning of infrastructure and utilities post-construction also has potential to affect the Snowy River EEC, although this will occur in areas already affected and will generally involve rehabilitation of disturbed habitat. The potential impacts associated with these activities are outlined below:

> Surface infrastructure and utilities

The construction of surface works and utilities will involve the construction and upgrades of access roads (including bridges), accommodation camps, construction compounds, subsurface utilities (communications), substations and power connections, ancillary construction facilities and wastewater outflows. Surface works will generally be located near intakes within Talbingo and Tantangara Reservoirs, Lobs Hole and within the plateau region of the project areaError! Reference source not found. Infrastructure and utilities would also transect parts of the Eucumbene River within the Lake Eucumbene Catchment (as well as other watercourses). Of particular relevance to the Snowy EEC is the upgrade of an existing crossing of the Marica Trail over the upper section of the Eucumbene River (a type 1 KFH) and the underboring of communications conduits. Several mitigation measures will be implemented to control construction related risks to the Snowy River EEC on the Eucumbene River including:

AE10: Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure construction to manage impacts of diffuse surface run-off on receiving watercourses

AE11: Rehabilitation of temporary roads and areas used for construction will occur in accordance with the Rehabilitation Plan

AE02: Bridges or culverts would be designed and constructed in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge 2003) where feasible.

AE03: Construction works within the channel of a permanent waterway with type 1 or 2 key fish habitat would allow some flow to maintain fish passage at all times and be staged to minimise the total disturbance at any given time.

AE12: Where possible, an exclusion buffer will be applied for road construction either side of a river except where bridges or other crossing structures are required.

AE13: Procedures for the management of woody debris disturbed during construction of bridges or other waterway crossings would be outlined within the AqHMP;

AE14: Where cable routes intersect permanent waterways containing type 1 or 2 key fish habitat, construction will be carried out in a manner that does not obstruct flow and minimises habitat disturbance

AE15: Wastewater, including tunnel process water, will be treated and released in accordance with the measures specified in the Water Management Plan

AE16: Wastewater outlets would be designed and positioned to minimise the footprint of hard bank engineering and prevent bank scouring and erosion

AE04: A Weed, Pest and Pathogen Management Plan will be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens.

> Tunnel excavation and groundwater drawdown

Groundwater drawdown from tunnel excavation has the potential to impact the aquatic habitat within the Snowy River EEC and organisms that reside within them due to loss or reduction in the availability of habitat, reductions in connectivity of habitat due to reduced stream flow, changes in flow regime of impacted streams and impaired water quality (see **Section 6.5**). Modelling of drawdown impacts suggests that possible periods of no flow are predicted overall to increase within sections of the Eucumbene River adjacent to the tunnel alignment. The section of the Eucumbene River predicted to experience these reductions in flow is part of the Snowy River EEC. This could result in impacts to this EEC and associated species. In the context of the wider EEC, however, such impacts would occur in a relatively small extent of its total area. The most severe predicted reductions in flow would also occur in the upper headwaters of the Eucumbene River, which provides relatively limited aquatic habitat compared with the much larger sections of the Eucumbene River further downstream. To help alleviate potential drawdown impacts, grouting of discrete fractures (caused during tunnel construction) that yield excess water and would be undertaken to reduce the actual overall tunnel inflow volume. As such, the likelihood of a reduction in the availability and connectivity of aquatic habitat following mitigation is assessed as Possible with a residual risk rating of Moderate.

> Transfer of water between Talbingo and Tantangara reservoirs

During the commissioning and operational phase of Snowy 2.0 water transfers between Talbingo and Tantangara reservoirs would occur. Water transfers between Talbingo and Tantangara reservoirs with potential to affect the Snowy River EEC include the potential for transfer of HAB taxa and the risk of fish diseases being transferred from Talbingo and Tantangara reservoirs to the Eucumbene River and Lake Eucumbene via the unidirectional Murrumbidgee-Tantangara Portal. Measures to minimise and manage the potential spread of pest algae, plants and fish disease would include the following:

AE01: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat.

AE19: The surveillance and management of HABs will be in accordance with existing Snowy Hydro procedures

AE18: Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel

> Maintenance and decommissioning of infrastructure and utilities

On completion of the main works, temporary construction elements such as temporary access roads would l be decommissioned and subject to ongoing rehabilitation and revegetation. As the Marica Trail will be permanent this will not affect the upper Eucumbene River. Maintenance and decommissioning works over the broader plateau region have the potential to cause indirect changes to water quality from diffuse surface run-off and the risk of spread aquatic weeds and pest fish being spread by plant and equipment operating throughout the study area. The following mitigation measures will be in place to manage these risks:

AE20: Best practise erosion and sediment controls as outlined in the Erosion and Sediment Control Plan would be adopted for all aspects of road and infrastructure decommissioning to manage impacts of diffuse surface run-off on receiving watercourses. Ongoing road maintenance will be managed in accordance with existing Snowy Hydro procedures.

AE01: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat.

AE11: Rehabilitation of temporary roads and areas used for construction will occur in accordance with the Rehabilitation Plan

AE21: Watercourses subject to disturbance from construction and / or decommissioning would be rehabilitated to ensure that they are hydraulically and geomorphologically stable

AE09: Contaminated sediments and soils posing a risk to aquatic habitats will be managed in accordance with the Dredging and Excavated Materials Management Plan (DEMMP) and/or Aquatic Habitat Management Plan (AqHMP)

AE04: A Weed, Pest and Pathogen Management Plan will be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan will:

AE22: Water released during tunnel and station dewatering for operations will be undertaken in accordance with operational procedures and management plans and in accordance with relevant licences

With the mitigation measures outlined above in place, the residual risks to the Snowy River EEC in the Lake Eucumbene Catchment are considered to be low to moderate. Given the relatively small footprint and short construction timeframe of direct impacts to habitat of the Eucumbene River, adverse effects on the Snowy River EEC to the extent that it's local occurrence or composition is placed at risk of extinction are not expected.

Table 1-28 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Occs	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 1-29 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume Reservoir	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Snowy River EEC**												Oc	Oc	Oc	Oc		
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

		Indirect - changes to water quality from diffuse surface run-off	X	X	X	X			X
		Indirect – spread of aquatic weeds and pest fish	X	X	X	X	X		X
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat							X
Operation	Transfer of water between Talbingo and Tantangara reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence							
		Direct - Hydraulic entrainment and entrapment of biota	X		X				
		Indirect - Impact of fish transfer on fish ecology	X	X	X	X	X	X	
		Indirect - plant and phytoplankton transfer leading to HABs	X	X	X	X		X	X
		Indirect - proliferation of non-native aquatic plants	X		X	X		X	X
		Indirect - fish disease transfer leading to mortality	X	X	X	X	X	X	X
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X	X	X	X			X
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X						
		Indirect - changes to water quality from diffuse surface run-off	X	X	X	X			X
		Indirect – spread of aquatic weeds and pest fish	X	X	X	X	X		X

d. ***In relation to the habitat of a threatened species, population or ecological community:***

i. ***the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and***

ii. ***whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and***

iii. ***the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.***

Based on the impacts and locations identified in **Table 1-29**, the extent of impacts to the Snowy River EEC habitat as per criteria d) i-iii are addressed and summarised in **Table 1-30** below.

Table 1-30 Assessment of criteria d) i-iii (potential impacts to habitat) as a result of the Project

Criteria	Lake Eucumbene Catchment	Comment
(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity	Direct habitat disturbance will occur at three locations on the upper section of the Eucumbene River and its unnamed tributaries where communications cables will transect the river. The upgrade of the Marica Trail crossing over the Eucumbene River will include a disturbance footprint up to an approximately 30 m reach. Groundwater drawdown would also have a potential impact on aquatic habitat within this catchment	No other habitat within the Snowy River EEC is expected to be directly modified or removed as a result of the project. Some aquatic habitat may be modified or removed as a result of groundwater drawdown, although this would mostly occur in the upper headwaters of the Eucumbene River, which provides relatively limited aquatic habitat compared with the much larger sections of the Eucumbene River further downstream
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity	Provided that an appropriate crossing structure is constructed for the Marica Trail crossing (as per Fairfull and Witheridge, 2003) and that appropriate methods (such as under boring) are used for the communications cable routes then habitat would not become isolated or fragmented during construction. Some flow would be maintained at all times during construction on this type 1 waterway	-
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality.	The habitat in the upper part of the Eucumbene River that would be directly affected consists of generally cleared land with minimal riparian vegetation. It is not known to support any threatened species.	-

e. ***Whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).***

Critical habitat refers only to those areas listed in the Register of Critical Habitat kept by NSW DPI (Fisheries). This question is not applicable, as no critical habitat has been listed for the Snowy River EEC.

f. ***Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.***

A Priorities Action Statement exists for the Snowy River EEC:

https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/endangered/snowy-river/priorities-action-statement-actions-for-snowy-river-aquatic-endangered-ecological-community

The recovery objectives and actions of the PAS mostly relate to conservation works, research and monitoring, agency consultation and community engagement. Impacts from Snowy 2.0 that are related to these objectives and actions mostly include habitat rehabilitation and pest eradication/control. All of the mitigation actions to minimise disturbance, rehabilitate disturbed habitat, and to minimise and monitor for pests and diseases would be consistent with the recovery actions of the PAS.

g. ***Whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.***

KTPs that could be facilitated by project activities are identified below.

> Degradation or native riparian vegetation along New South Wales water courses (FM Act);

> Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act);

> Introduction of fish to waters within a river catchment outside their natural range (FM Act);

As discussed in item a) a number of mitigation and management measures would be implemented to address each of the KTPs listed above.

Conclusion

Provided that the mitigation measures outlined in item a) are implemented then the project is not expected to significantly impact the Snowy EEC, particularly in the upper reaches where crossing structures and communications conduits will transect the Eucumbene River. Indirect impacts from diffuse water quality and the potential for the spread of pests and diseases will be managed via standard erosion and sediment controls and a series of management and monitoring plans. Impacts to this EEC as a result of Snowy 2.0 are not, therefore expected to significantly affect the extent or composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction. The project is not inconsistent with a PAS and measures would be in place to minimise the potential for a KTP to be facilitated.

2 Tests of Significance (Environmental Protection and Biodiversity Conservation Act 1999)

Under the Commonwealth EPBC Act a Test of Significance (ToS) is required to determine whether a significant impact on any threatened species or TEC listed under the EPBC Act known or considered likely to occur on a site as a result of a Project. These assessments are guided by the *Matters of National Environmental Significance: Significant Impact Guidelines 1.1.*

The following EPBC Act listed entities are considered to be present or to have suitable habitat and a potential to occur within the study area and they or their habitats would be impacted upon by the project:

> Macquarie perch (*Macquaria australasica*) – Listed as endangered under the EPBC Act;

> Trout cod (*Maccullochella macquariensis*) – Listed as endangered under the EPBC Act; and

> Murray cod (*Maccullochella peelii*) - Listed as vulnerable under the EPBC Act.

For the purpose of this assessment, an 'important population' is a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:

> key source populations either for breeding or dispersal;

> populations that are necessary for maintaining genetic diversity, and/or

> populations that are near the limit of the species range.

Each species / population / EEC was assessed in terms of their likelihood to occur in areas potentially affected by the project. For the purpose of the assessment the study area was delineated into catchments based on the ecological and geographic context, hydrological connectivity, aquatic habitat types and the known distribution of key species. The extent of these catchments is indicated in **Figure 5-1** of the main report.

2.1 Macquarie perch (*Macquaria australasica*)

a. ***Lead to a long-term decrease in the size of an important population of a species.***

Based on literature and database reviews, results of eDNA surveys (EnviroDNA, 2019a, b) and field surveys for the Snowy 2.0 project, Macquarie perch are known to occur within the Lower Tumut River Catchment (below Blowering Reservoir), within the Mid and Lower Murrumbidgee River Catchments and within the Murray River Catchment to Hume Reservoir. For the purpose of this assessment, viable, self-sustaining natural populations within the natural range of Macquarie perch would be considered as 'important populations' although this is not stated in the national species recovery plan (DEE, 2018). Within NSW, areas where these populations occur include the Murrumbidgee River below 'Cooma Gorge' and upstream of Gigerline Gorge and the Adjungbilly Creek in the Tumut River catchment.

No direct impacts associated with Snowy 2.0 are expected in any of the catchments where Macquarie Perch are known to occur. Indirect impacts with the potential to affect Macquarie perch could only occur within the Mid Murrumbidgee Catchment. This would include the Murrumbidgee River below 'Cooma Gorge' and upstream of Gigerline Gorge. An important population of the species therefore has potential to be affected by the project activities. Project activities potentially affecting Macquarie perch in the Mid Murrumbidgee River Catchment relate to the transfer of water between Talbingo and Tantangara Reservoirs. The impacting processes from this activity with regards to Macquarie perch are discussed below.

> Indirect - Impact of fish transfer on fish ecology

The impact of fish transfer on Macquarie perch relates to the transfer of redfin perch into Tantangara Reservoir from Talbingo Reservoir and ultimately into the Mid Murrumbidgee River below Tantangara dam wall, where Macquarie perch are known to occur and redfin perch are currently absent. Redfin perch have been linked with the decline in numbers of Macquarie perch (NSW DPI, 2017) through competition for food, such as fish larvae and aquatic macroinvertebrates, and via direct predation on Macquarie perch larvae and juveniles. The proposed addition of a fish barrier control on Tantangara dam wall as part of Snowy 2.0 works would aim to prevent any potential impact on Macquarie perch below the dam wall by preventing the potential transfer of redfin perch from Tantangara Reservoir, should they establish there following operation of Snowy 2.0.

As part of the fish transfer impact assessment, the residual risk to Macquarie perch following the implementation of the barrier control would be moderate (**Section 7.2.3** of main report).

> Indirect - plant and phytoplankton transfer leading to HABs

The transfer of water from Talbingo Reservoir into Tantangara Reservoir has the potential to change the distribution and abundance of phytoplankton assemblages within Tantangara Reservoir and ultimately within the Mid Murrumbidgee River downstream of the Tantangara dam wall (via environmental releases). As part of the plant and phytoplankton transfer impact assessment, the risk to Macquarie perch would be low (see **Section 8.2.4** of main report).

> Indirect - Fish disease transfer leading to mortality

The main fish disease with relevance to the project is EHNV (**Section** Error! Reference source not found.. of the main report). Although outbreaks of EHNV are rare and EHNV has not been previously detected in either Talbingo or Tantangara Reservoirs, as redfin perch, the primary vector for this disease is present in Talbingo, there is potential for EHNV to be present in very low quantity or establish within the reservoir at some point in the future. In the event that Snowy 2.0 leads to the transfer and establishment of redfin in the future, this would lead to an increase in the risk of an outbreak of EHNV within Tantangara Reservoir. If an outbreak occurs within Tantangara Reservoir, water released from the dam into the Mid-Murrumbidgee River may contain the disease. As Macquarie Perch have been shown to be susceptible to EHNV under laboratory conditions, it is possible that these fish could be affected if they were to come in contact with the disease, although there are no recorded instances of Macquarie Perch infection with EHNV from the wild (Hick et al, 2019).

Given the apparently diminishing frequency of EHNV outbreaks and the fact that EHNV has not been recorded to date in Talbingo, the likelihood of an EHNV outbreak in Tantangara, should redfin perch establish there, is considered possible. The likelihood of an outbreak of EHNV subsequently spreading to the mid-Murrumbidgee River and affecting the population of Macquarie Perch present is considered unlikely following installation of the fish barrier which would be expected to substantially decrease the viral load entering the catchment in the event of an outbreak of EHNV in Tantangara.

In summary the mitigation measures that would be implemented to address issues relating to water transfer would include:

AE01: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat

AE22: Installation of fine mesh screens to prevent transfer of key pest species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee-Eucumbene tunnel

Based on the above, project activities would not be expected to have an adverse effect on Macquarie perch such that it would lead to a long-term decrease in the size of the population in the Mid Murrumbidgee Catchment.

b. ***Reduce the area of occupancy of an important population.***

As described in item a) there are several pathways via which water transfers between Talbingo and Tantangara Reservoirs can create pathways to impact upon the Mid Murrumbidgee population of Macquarie perch. In particular, the introduction of redfin perch to the Mid Murrumbidgee Catchment could reduce their area of occupancy through competition for food and resources and potentially transfer of disease. As discussed in item a), the movement of redfin perch downstream of Tantangara Reservoir into the Mid Murrumbidgee River Catchment would be restricted by a barrier and other mitigation measures including monitoring of pest fish and disease surveillance in key locations within the project area.

c. ***Fragment an existing important population into two or more populations.***

Potential project impacts associated with water transfer would not directly affect Macquarie perch in the Mid Murrumbidgee Catchment such that the existing population would become fragmented.

d. ***Adversely affect habitat critical to the survival of a species.***

According to the Macquarie perch National Recovery Plan (DEE 2018), areas of habitat considered as critical to the survival of Macquarie perch (as relevant to the project) include:

> all areas within the species range which are characterised by flowing runs or riffles and small complex rock piles;

> current area of occupancy of the species'; and

- unoccupied habitat within the species' natural range into which the species could disperse, be stocked or be translocated.

Project activities and potential impact pathways as described in item a) would not directly affect critical habitat for the Macquarie perch.

e. ***Disrupt the breeding cycle of an important population.***

Provided that the mitigation and management measures outlined in items a)-d) are implemented, then project activities are not expected to directly disrupt the breeding cycle of Macquarie perch in the Mid Murrumbidgee Catchment.

f. ***Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.***

Provided that the mitigation and management measures outlined in items a)-d) are implemented then project activities are not expected to modify, destroy, remove or isolate or decrease the availability or quality of habitat of Macquarie perch in the Mid Murrumbidgee Catchment.

g. ***Result in invasive species in that area harmful to a vulnerable species becoming established in the vulnerable species' habitat.***

As identified in item a), the transfer of redfin perch into Tantangara Reservoir could occur as a result of project operation. Macquarie perch are not known to occur in this catchment. The subsequent transfer of redfin perch into the Mid-Murrumbidgee River, should they establish in Tantangara, is expected to be prevented via the installation of a barrier to prevent all fish transfer through Tantangara Dam. With these measures in place it is not expected that redfin would become established in the Mid Murrumbidgee Catchment below Tantangara dam wall.

h. ***Introduce disease that may cause the species to decline.***

As identified in item a) and the impact assessment (**Section 7.2.5**). of the main report), the likelihood of an outbreak of EHNV subsequently spreading to the mid-Murrumbidgee River and affecting the population of Macquarie Perch present is considered unlikely following installation of the fish barrier which would be expected to substantially decrease the viral load entering the catchment in the event of an outbreak of EHNV in Tantangara. In order to mitigate the threat of EHNV, the following relevant mitigation measures will be implemented:

AE01: An Aquatic Habitat Management Plan (AqHMP) will be prepared and implemented to guide management of impacts to aquatic habitat.

i. ***Interfere substantially with the recovery of the species.***

The 'National Recovery Plan for Macquarie Perch (DEE 2018) outlines recovery actions to protect the species from long term decline:

https://www.environment.gov.au/system/files/resources/bdee49ef-45da-4eb7-b548-bcfce460a21b/files/recovery-plan-macquarie-perch-2018.pdf

Recovery actions of particular relevance to project activities potentially impacting on Macquarie perch include the following:

- Protect Macquarie perch from competition with and predation by introduced fish species; and
- Protect Macquarie perch populations from outbreaks of disease and parasites;

As identified in items a), g) and h), several measures will be implemented as part of the project that will minimise the potential for interference with the species recovery in the Mid Murrumbidgee Catchment.

Conclusion

The project has the potential to affect Macquarie perch populations in the Mid Murrumbidgee Catchment where the transfer of water (fish and disease) has a moderate residual risk. The project has the potential to transfer introduced fish and EHNV into this catchment which are known threats listed in the recovery plan for this species. Mitigation measures would help to reduce risks to a low to moderate level and would not substantially interfere with the recovery plan for this species.

2.2 Trout cod (*Maccullochella macquariensis*)

a. ***Lead to a long-term decrease in the size of an important population of a species.***

Trout cod is listed as endangered under the EPBC Act. Within the study area it is known to occur within Talbingo Reservoir, within the Mid and Lower Murrumbidgee River Catchments and within the Murray River Catchment to Hume Reservoir. It also has a moderate likelihood of occurrence within the Upper Tumut River Catchment and the Yarrangobilly River Catchment. Project activities would only have the potential to impact on trout cod occurring in Talbingo Reservoir, the Yarrangobilly River Catchment and the Mid Murrumbidgee Catchment. All of these populations are considered to be derived from fish stocking.

It is unclear within the National Recovery Plan for Trout cod whether these populations constitute 'important populations', so have therefore been assessed regardless.

Project related activities that have the potential to affect this species within these catchments include:

> Construction of intakes and dredging works

> Sub-aqueous edge placement

> Surface infrastructure and utilities

> Transfer of water between Talbingo and Tantangara Reservoirs

> Maintenance and decommissioning of infrastructure and utilities

The construction of intakes and any associated dredging works within Talbingo Reservoir would have the potential to cause a number of direct and indirect impacts to fish within this waterbody. These include the removal/modification of habitat, hydraulic entrainment from dredging operations, noise/vibration from blasting, changes to water quality and dredging related noise. These impacts have been assessed in detail **Section 7.2** if the main AEA report. In summary, the residual risk from most of these impacting processes on trout cod have been assessed as low given the relatively small area that would be affected by these activities and the mobile nature of trout cod allowing it to avoid (to some extent) many of these impacts. The exception to this is for the impact of noise and vibration from blasting, which was assessed as a moderate risk to trout cod within Talbingo Reservoir.

The subaqueous edge placement of spoil material within Talbingo Reservoir has the potential to remove/modify trout cod habitat, displace/eradicate trout cod and indirectly impact these fish due to changes in water quality as a result of spoil placement. These impacts have been assessed in detail in **Section 7.3** or the main AEA report. In summary, the residual risks from these impacts on trout cod within Talbingo Reservoir have been assessed as low, with the exception of changes to water quality which would have a moderate risk level with respect to trout cod. Although it is possible that they would temporarily experience indirect, sub-lethal effects due to high levels of turbidity, they would most likely move to areas within the reservoir or areas within feeder creeks and river arms with suitable habitat that are not subjected to high levels of turbidity.

The construction of surface infrastructure and utilities (i.e. access roads, accommodation camps, construction compounds, subsurface utilities, power substations, ancillary construction facilities and wastewater outflows) has the potential to impact on trout cod within Talbingo Reservoir and the Yarrangobilly River. A detailed impact assessment for the construction of surface infrastructure and utilities has been undertaken in **Section 7.4** of the main AEA report. In summary, it was stated that the cumulative effects of habitat removal and disturbance, impediment to movement of fish and macroinvertebrates, diffuse surface water run-off and point source inputs of wastewater have potential to impact on threatened species known or potentially occurring within the reservoirs and watercourses (including trout cod), although the residual risk from these impacts was assessed as low, given that appropriate road design and sediment and erosion controls would be put in place.

As trout cod are currently stocked into Talbingo Reservoir, any potential impacts on this species from construction related activities associated with Snowy 2.0 would be assuaged by the replenishment of individuals via the ongoing stocking of trout cod in this reservoir by DPI.

The transfer of water between Talbingo and Tantangara Reservoirs is another potential pathway that could impact on trout cod within various catchments, including Talbingo Reservoir, the Yarrangobilly River and the Mid Murrumbidgee River Catchment. Impacting processes from the transfer of water (and where they have been assessed within the report) include:

> Direct - Hydraulic entrainment and entrapment of biota (**Section 7.2.2**)

> Indirect - Impact of fish transfer on fish ecology (**Section 7.2.3**)

> Indirect - plant and phytoplankton transfer leading to HABs (**Section 7.2.4**)

> Indirect - proliferation of non-native aquatic plants (**Section 7.2.4**)

In summary, the residual risks from each of these impacting processes was assessed as being either low to moderate for trout cod, with the transfer of redfin (within the Mid Murrumbidgee River Catchment) as being the process with the highest risk (moderate). Mitigation measures such as fish barrier controls and surveillance monitoring would be employed to help manage these risks throughout the duration of the project.

The maintenance and decommissioning of infrastructure and utilities (i.e. for temporary access roads, accommodation camps, construction portals, construction staging compounds, wastewater and wastewater management infrastructure and barge launch facilities) has the potential to impact on trout cod within both Talbingo Reservoir and the Yarrangobilly River. Impacting processes from this activity include:

> Direct - removal/modification of habitat and associated biota

> Indirect - changes to water quality due to tunnel dewatering (point source)

> Indirect - changes to water quality from diffuse surface run-off (diffuse)

> Indirect – spread of aquatic weeds and pest fish

A detailed impact assessment for the maintenance and decommissioning of infrastructure and utilities has been undertaken in **Section 7.3**. In summary, the residual risk to trout cod within both Talbingo Reservoir and the Yarrangobilly River was assessed as being low for all impacting process pathways listed above.

Based on the above assessments, it is expected that project activities within these catchments would not lead to a long-term decrease in the size of these populations.

b. ***Reduce the area of occupancy of an important population.***

Important habitat (woody debris, rocks and boulders) is abundant throughout Talbingo reservoir and in the downstream reaches of Yarrangobilly River, however, it is expected that there would be only a small reduction in this habitat due to Snowy 2.0. The proposed road crossing in Talbingo Reservoir would not represent a complete or permanent obstruction to fish passage, nor does trout cod undertake migration as part of reproduction. As described above, potential impacts to trout cod habitat due to the Snowy 2.0 are likely to be relatively small-scale and temporary and would not result in a significant reduction in the area of occupancy of this species.

c. ***Fragment an existing important population into two or more populations.***

As described in (a), the impacting processes that have been assessed as having a moderate risk to trout cod would involve:

> Noise and vibration from blasting during the construction of the intake structures

> Changes to water quality as a result of excavated material placement activities within Talbingo Reservoir

> Transfer of redfin perch into the Mid Murrumbidgee River Catchment

Given the nature of these impacting processes and how they would interact with trout cod populations, it is not expected that these would significantly fragment a population of trout cod within the study area into two or more populations.

d. ***Adversely affect habitat critical to the survival of a species.***

No critical habitat for the species is identified within the study area.

e. ***Disrupt the breeding cycle of an important population.***

Trout cod spawn annually during late October to early November and attach their adhesive eggs to hard surfaces such as rocks and woody debris. Increased suspended sediment from excavated material placement activities and its deposition within Talbingo Reservoir may have the potential to smother this habitat, thus potentially disrupting the breeding cycle of this species within Talbingo Reservoir. Suitable habitat does exist throughout much of Talbingo Reservoir and within many of the feeder creeks, however, where trout cod could potentially move into that is not subjected to high levels of turbidity. In addition, this population is stocked into the reservoir and no evidence of breeding has been detected. The risk of this impacting process affecting trout cod has been assessed as moderate.

f. ***Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.***

Some small areas of preferred trout cod habitat are expected to be directly removed/modified due to project related activities such as placement of excavated material and construction of intake structures within Talbingo Reservoir. Given the small areas that would be directly impacted, this is not considered to be significant and is assessed as having a low residual risk to Trout cod. Changes to water quality through increased suspended sediment and its subsequent deposition in the fringing margins of the reservoir may impact on some trout cod habitat. This impacting process would be temporary however and given that suitable habitat exists throughout much of Talbingo Reservoir and within many of the feeder creeks that may not be subjected to high levels of suspended sediment and deposition, the impact on trout cod habitat has been assessed as a moderate risk.

g. ***Result in invasive species in that area harmful to a vulnerable species becoming established in the vulnerable species' habitat.***

There is a potential that redfin perch could be transferred from Talbingo Reservoir into Tantangara Reservoir as a result of Snowy 2.0. The potential subsequent spread of redfin perch into the Trout Cod habitat in the mid-Murrumbidgee River below Tantangara Dam is not expected following the installation of a fish barrier to prevent the movement of any fish downstream into this catchment.

Further information regarding the mechanisms and processes of these impact pathways is provided in **Section 7.2.3** of the main AEA report.

h. ***Introduce disease that may cause the species to decline.***

As trout cod are not considered susceptible to EHNV, there is no potential for Snowy 2.0 to introduce any diseases that may cause the species to decline.

i. ***Interfere substantially with the recovery of the species.***

The recovery objectives and actions within these documents in relation to Trout cod mostly surround conservation works, research and monitoring, agency consultation and community engagement. Actions and objectives from these recovery plans that are related to the Snowy 2.0 project mostly include habitat maintenance/improvement, the protection/establishment of stocked populations and the minimisation of risks from introduced pest species. The construction and operation of Snowy 2.0 are unlikely to significantly interfere with these objectives.

Conclusion

The Project has the potential to affect Trout cod populations known to occur in Talbingo Reservoir and the Mid Murrumbidgee River Catchment through a number of impacting processes, of which have been assessed as having a low to moderate residual risk to Trout cod. The Project has the potential to transfer introduced fish and disease across catchments which are known threats listed in the recovery plans for this species. Various mitigation measures would help to alleviate any risks from these impacting pathways and are consistent with the actions and objectives set out in the recovery plans for this species.

Given that the trout cod populations within Talbingo Reservoir are most likely not self-sustaining and have been stocked in the past, any potential impacts on this species from construction related activities associated with Snowy 2.0 would be assuaged by the replenishment of individuals via the ongoing stocking of trout cod in this reservoir by DPI. Thus a significant impact to trout cod is not expected.

2.3 Murray cod (*Maccullochella peelii*)

a. ***Lead to a long-term decrease in the size of an important population of a species.***

Murray cod is listed as vulnerable under the EPBC Act. Within the study area it is known to occur within Blowering Reservoir Catchment, the Mid and Lower-Murrumbidgee River Catchments, the Murray River to Hume Reservoir Catchment and the Swampy Plain River Catchment. It has a moderate likelihood of occurrence within the Lower Tumut River Catchment. As indicated in **Table 2-1** and **Table 2-2** project activities would only impact on Murray cod occurring in the Mid Murrumbidgee Catchment. None of the catchments within the study area are considered to include 'important populations' as identified in Table 1 of the Murray cod National Recovery Plan (National Murray Cod Recovery Team, 2010). As such, project activities would not lead to a long-term decrease in the size of an important population.

b. ***Reduce the area of occupancy of an important population.***

None of the catchments within the study area are considered to include 'important populations' as identified in Table 1 of the Murray cod National Recovery Plan (National Murray Cod Recovery Team, 2010). Project activities would not therefore reduce the area of occupancy of an important population.

c. ***Fragment an existing important population into two or more populations.***

None of the catchments within the study area are considered to include 'important populations' as identified in Table 1 of the Murray cod National Recovery Plan (National Murray Cod Recovery Team, 2010). Project activities would not therefore fragment an existing important population.

d. ***Adversely affect habitat critical to the survival of a species.***

No critical habitat for the species is identified within the study area.

e. ***Disrupt the breeding cycle of an important population.***

None of the catchments within the study area are considered to include 'important populations' as identified in Table 1 of the Murray cod National Recovery Plan (National Murray Cod Recovery Team, 2010). Project activities would not therefore disrupt the breeding cycle of an important population.

f. ***Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.***

   Project activities are not expected to modify, destroy, remove or isolate or decrease the availability or quality of habitat of Murray cod in the Mid Murrumbidgee Catchment

g. ***Result in invasive species that area harmful to a vulnerable species becoming established in the vulnerable species' habitat.***

   As identified in item a), the transfer of redfin perch into Tantangara Reservoir could occur as a result of project operation. Murray cod are not known to occur in this catchment. The subsequent transfer of redfin perch into the Mid-Murrumbidgee River, should they establish in Tantangara, is expected to be prevented via the installation of a barrier to prevent all fish transfer through Tantangara Dam. With these measures in place it is not expected that redfin would become established in the Mid Murrumbidgee Catchment below Tantangara dam wall.

h. ***Introduce disease that may cause the species to decline.***

As Murray cod are not considered susceptible to EHNV, there is no potential for Snowy 2.0 to introduce any diseases that may cause the species to decline.

i. ***Interfere substantially with the recovery of the species.***

Provided that all of the mitigation measures as outlined in items g) and h) are implemented, project related impacts are not expected to interfere substantially with the recovery of Murray cod in the Mid-Murrumbidgee River Catchment and the recovery actions outlined in the Murray cod National Recovery Plan.

<u>*Conclusion*</u>

Murray cod occurring in the Mid Murrumbidgee River Catchment are not considered part of an 'important population'. Water transfers between Talbingo and Tantangara Reservoirs as part of the operation of Snowy 2.0 have potential to result in an invasive species becoming established in Murray cod habitat However, following the installation of a barrier to fish movement at Tantangara Dam, no impact is expected. Thus a significant impact to Murray cod is not expected.

Table 2-1 Likelihood of interactions between threatened species and project impacts

Low	= Low likelihood of occurrence – does not require assessment
Mod	= Potential species / impact interaction – Moderate likelihood of occurrence
Oc	= Potential species / impact interaction – Occurs
X	= Project activity with potential to impact on catchment

Table 2-2 Interactions between threatened species and project activities

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
	Species Distribution	**Murray cod**					Oc	Mod				Oc	Oc				Oc	Oc	
Construction	Construction of intakes and dredging works	Direct - removal/modification of habitat and associated biota within the dredge and excavation footprints	X						X										
		Direct – hydraulic entrainment of fish and mobile invertebrates within dredge areas;	X						X										
		Direct – noise and vibration from blasting	X						X										
		Indirect - changes to water quality (via sediment mobilisation during dredging)	X						X										
		Indirect - Dredging related noise	X						X										
	Sub-aqueous edge placement	Direct - Loss/modification of aquatic habitat due to smothering	X						X										
		Direct - Changes to sediment quality within the proposed placement areas	X						X										
		Indirect - Changes to water quality	X						X										
	Surface infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X	X			X					
		Direct – temporary obstruction to fish passage	X							X	X			X					
		Direct – changes to water quality from point source discharges (i.e. waste water outlets)																	

Phase	Activity	Impact	Talbingo Reservoir	T2 Reservoir Catchment	Upper Tumut River Catchment	Yarrangobilly River Catchment	Blowering Reservoir Catchment	Lower Tumut River Catchment	Tantangara Reservoir	Upper Murrumbidgee River Catchment	Upper Tantangara Creek Catchment	Mid-Murrumbidgee River Catchment	Lower-Murrumbidgee River Catchment	Lake Eucumbene Catchment	Lake Jindabyne Catchment	Lower Snowy River Catchment	Murray River Catchment to Hume	Swampy Plain River Catchment	Geehi and M2 Reservoir Catchments
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					
	Tunnel excavation and groundwater drawdown	Indirect - Reduction in the availability and connectivity of aquatic habitat				X				X				X					
Operation	Transfer of water between Talbingo and Tantangara Reservoirs	Direct - stratification (temperature), light attenuation (turbidity) and turbulence																	
		Direct - Hydraulic entrainment and entrapment of biota	X						X										
		Indirect - Impact of fish transfer on fish ecology	X			X			X	X	X	X							
		Indirect - plant and phytoplankton transfer leading to HABs	X			X			X	X		X		X					
		Indirect – proliferation of non-native aquatic plants	X						X	X		X		X					
		Indirect - fish disease transfer leading to mortality	X			X			X	X	X	X		X					
	Maintenance and decommissioning of infrastructure and utilities	Direct - removal/modification of habitat and associated biota at infrastructure locations	X			X			X	X				X					
		Indirect – changes to water quality in reservoirs due to tunnel dewatering (assumes dewatering of tailrace tunnel only into Talbingo Reservoir)	X																
		Indirect - changes to water quality from diffuse surface run-off	X			X			X	X				X					
		Indirect – spread of aquatic weeds and pest fish	X			X			X	X	X			X					